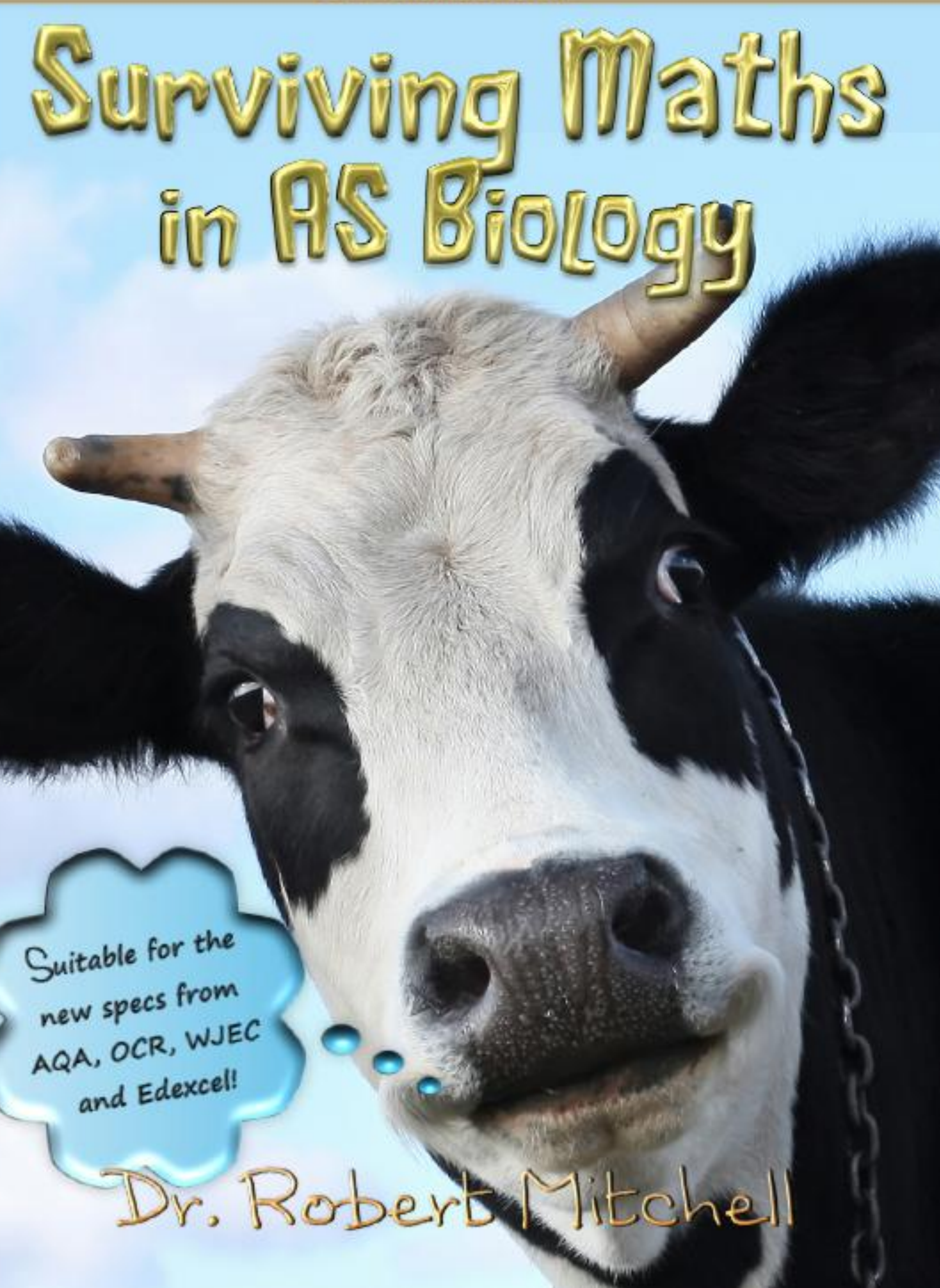
CT Publications



CT Publications

Surviving Maths in AS Biology

by

Dr Robert Mitchell

www.SurvivingMathsInASBiology.co.uk

A catalogue record for this book is available from the British Library

ISBN 978-1-907769-07-8
First published in September 2010 by
CT Publications

Published by
CT Publications*
40 Higher Bridge Street
Bolton
Greater Manchester
BL1 2HA

First printing September 2010
10 9 8 7 6 5 4 3 2 1

*CT Publications is owned by *Chemistry Tutorials* located at the same address.

Contents

Acknowledgements

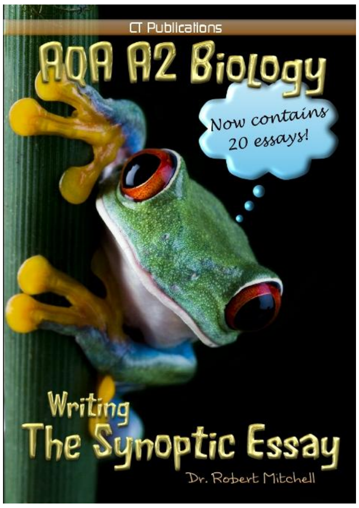
I would like to thank Denise for her infinite patience, her reading and proofing skills and having the unending ability to encourage and support the production of this work. Thanks also to my Mum, Joyce and Brother, Colin for just being there.

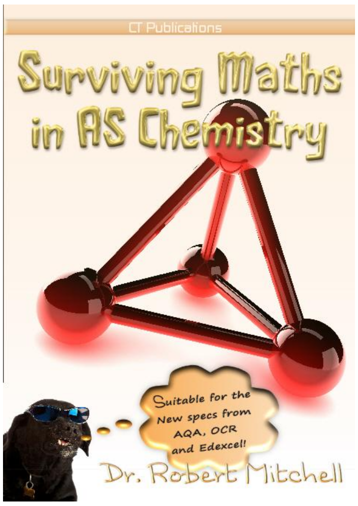
About the author

Rob is a private tutor in chemistry and biology in Bolton. He's formerly worked in medical research as technician, research assistant and post-doctoral researcher and has contributed to the publication of over 40 research papers. During a varied career in science, he's been a project leader in industry, a lecturer and examiner and blogs daily as *Chemicalguy*. He likes dogs, and pies, going to the movies and walking!

Other books by the author

AQA A2 Biology; Writing the Synoptic Essay	May 2010
Surviving Maths in AS Chemistry	August 2010
Ultimate Exam Preparation; AQA Chemistry Unit 1	October 2010 (in press)
Ultimate Exam Preparation; AQA Biology Unit 1	November 2010 (in press)
Biofuelishness (Popular Science)	December 2010 (in press)





Preface

Love it or hate it, you can't escape from doing maths in biology A-level. Since the introduction of the new-style specifications in 2008, the exam papers have included between 10 - 30% calculation and mathematical transformations. In the ISA or EMPA parts of the specifications this can increase to almost 50%. This means that those of you wanting to secure the grade A, or A* qualifications will be unlikely to achieve it without mastering the mathematical principles.

All exam boards publish the same set of *Mathematical Requirements*. While these are a basic set of criteria, I have found over the years that students often struggle with these concepts to the point that they can impact severely on the outcome in their exams. Part of the reason for this is that students often do not link and carry forwards some of the material from the GCSE. Even when they do, being able to calculate proportions in a GCSE maths class, for example is not necessarily an indicator of them being able to apply proportional changes into an investigation into enzyme activity in A-level biology.

This book aims to put this right! It is split into four main sections. *Section 1* covers the basic mathematical requirements outlined in the specifications using examples from the AS biology syllabus. *Section 2* then systematically covers all the AS mathematical content of the biology courses giving you simple and robust techniques for getting these calculations right every time! *Section 3* will then give you many examples of exam-style questions using the styling from AQA, Edexcel, OCR and WJEC. These of course come with mark schemes and a breakdown of the points so you can see how they are awarded in *Section 4*.

As with all the books from CTPublications the emphasis is on showing you how to do the content and get the exam points rather than helping you understand why you are doing it. I wish you the very best of luck to you all in your exams and future careers.

Dr Robert Mitchell
Summer 2010

Student resources

I publish two regular blogs covering various aspects of studying A-level chemistry and biology. All updates on new products and services are posted on these blogs **before** any other announcements. They are found at:

www.chemicalguy.wordpress.com [chemistry]
www.howscienceworks.wordpress.com [biology]

Pop along to this book's dedicated website for some more exam questions and worked examples.

www.SurvivingMathsInASBiology.co.uk

I also recommend using www.thestudentroom.co.uk for free help and support.

How to use this book

Also consider: 1. Lose the book 2. Buy it again 3. Write an excellent review on Amazon.co.uk or CTPublucations.co.uk, and 4. Recommend the book to all your classmates, teachers, head of science and college library book-buying officer. ☺

So many books show you *what you need to know* but miss out the obvious! How to do it! You should assume you know nothing and read through **the entire** book. You'll find an *End of Section Test* at ... errm the end of each section which you should complete before attempting the exam questions. Always, always, always monitor your performance and be critical of your own answers when marking your efforts. If you always work on fixing the weaker areas you will gain the most improvement in the least time!

You will also notice the 💣 placed strategically throughout. This symbol infers that those points are common mistakes you **must** be aware of and avoid.

The terms *sig fig* and *dp* refer to the number of significant figures and decimal places respectively that a number is rounded to.

Section 1: Mathematical Requirements

All exam boards publish a similar set of mathematical criteria. These are a series of statements that identify what you should be able to understand, or do, on entry into the AS level. Most of it might be the stuff you'd prefer to forget, or prefer not to remember that you never knew how to do it in the first place! Work through the following material even if you don't like it, you'll be glad you did later. I've also included a section on the How Science Works aspects which will be expanded on later in Section 2 and 3.

<table>
<tr><th>Reference</th><th>Relevant Topics</th></tr>
<tr><td colspan="2">Arithmetical and numerical computation</td></tr>
<tr><td>Recognise and use expressions in decimal and standard form.
Use ratios, fractions and percentages.
Make estimates of the results of calculations (without using calculators).
Use calculators to find and use power, exponential and logarithmic functions.</td><td>All calculations involving study data interpretation

Estimation will form a part of field data collection and in interpretation of experimental data during ISA/EMPA.</td></tr>
<tr><td colspan="2">Handling data</td></tr>
<tr><td>Use an appropriate number of sig fig.
Find arithmetic means.
Construct and interpret frequency tables and diagrams, bar charts and histograms.
Understand simple probability.
Understanding the principles of sampling as applied to scientific data.
Understand the terms mean, mode, median and standard deviation.
Use a scatter diagram to identify a correlation between two variables.
Use a simple statistical test.</td><td>A core component of all quantitative work at AS and A2 and is of particular relevance to the practical aspects of ISA and EMPA.

The data handling and data transformation aspects will be repeatedly explored in all practical work.</td></tr>
<tr><td colspan="2">Algebra</td></tr>
<tr><td>Understand & use symbols =, <, >, α, ~.
Change the subject of an equation.
Substitute numerical values into algebraic equations using appropriate units for physical quantities.
Solve simple algebraic equations.
Use logarithms for quantities which range over several orders of magnitude.</td><td>Symbols used appropriately in calculations or comparisons. Rearranging equations, substituting in values, solving and changing units are all core skills that will be tested in the context of all quantitative analysis.
Simple equation rearrangements will be tested in the context of magnification and heart/breathing rate calculations.</td></tr>
<tr><td colspan="2">Graphs</td></tr>
<tr><td>Translate information between graphical, numerical and algebraic forms.
Plot two variables from appropriate data.
Determine the slope and intercept of a linear graph and calculate the rate of change from a graph showing a linear relationship.
Draw and use the slope of a tangent to a curve as a measure of rate of change.</td><td>The graphical component will mainly be relevant for the practical work, particularly in the context of experiments involving enzyme activity, osmosis (AS), estimations of distribution and population studies (A2).</td></tr>
<tr><td colspan="2">Geometry</td></tr>
<tr><td>Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects.
Calculate circumference and areas of circles, surface areas and volumes of regular blocks and cylinders when provided with appropriate formulae.</td><td>All aspects of light and electron microscopy, and structures of cells and organelles.

Surface area to volume ratio in the context of size and adaptations require a theoretical calculated model for interpretation.</td></tr>
</table>

Arithmetical and numerical computation

Selecting the right calculator

Given the importance of the mathematical component of AS biology to your overall A-level success, it is imperative that you buy the right calculator early on and become *very* familiar with how to use it. You cannot just assume that the one you used at GCSE will make do. The range and complexity of the functions your calculator will need to have increases exponentially (pun very much intended!) in A-level. Here are just a few other things to consider before you part with your money on the shiny new abacus:

- **Always** carry a spare calculator battery with you, particularly at exam time … *Sod's Law* states that it will go just as the exam is about to start!
- **Never** throw away the instruction leaflet … at this point you don't know for sure what you will be using it for.
- **Before** you buy the calculator, **check** the requirements for the other subjects you do, particularly if you do mathematics, physics or chemistry … a multitude of other functions such as statistical analysis or graphical functions may be required.

When selecting an appropriate calculator, ensure that it:

- Is described as a *scientific calculator and c*an calculate numbers in the range at least $1x10^{-14}$ *to* $1x10^{24}$
- *Statistical* functions such as *mean* and *standard deviation* and a *random number* generator will be a useful (but not essential) feature.
- Is able to do the following *logarithmic* functions; $\boxed{\log}$ $\boxed{\ln}$
- Can express numbers in *standard form* using either $\boxed{x10^x}$ or $\boxed{\exp}$
- Can easily do squares, powers and square roots using $\boxed{x^2}$ $\boxed{x^n}$ $\boxed{\sqrt{n}}$

Fractions, ratios, percentages and Stuff

The same numerical value can be expressed in different ways. For example, the decimal number 0.005 is the same as the fraction $\frac{1}{200}$ and can be expressed as $5x10^{-3}$ in standard form. It can also be expressed as a ratio of *one in two hundred* or as 0.5%. In science, we use these different expressions of the same numbers in different contexts. The ways in which some of these different forms of a number are used is outlined below.

Fractions

- If the value is less than *one*, a fraction $\frac{x}{y}$ can be used to express it.
- While useful, fractions are not easy to compare. If I asked you which was smaller, $\frac{11}{17}$ or $\frac{12}{18}$ it is not easy to give a definitive answer.
- In such cases the number at the bottom, the *denominator*, can be made the same. When it is, it is called a *common denominator.*

Decimals

- The transformation of fractions into decimals leads to a result that can be compared instantly. In such cases, the common denominator effectively becomes 1.
- On a calculator this is done by dividing the top number of the fraction by the bottom number. In the above example, $\frac{11}{17}$ becomes 0.647 and $\frac{12}{18}$ becomes 0.667.
- This simple transformation now shows that $\frac{11}{17}$ is smaller than $\frac{12}{18}$.

Standard form

- Decimals have limited use when a number becomes very large or very small. In such cases, standard form is used to provide a consistent way of presenting and handling the number.
- Numbers in standard form are usually seen as x.yz x 10^n where x lies in the range between 1 and 9 and n can be a *negative* or *positive* number.
- The fraction $\frac{1}{120}$ has a decimal value of 0.00833. In standard form this becomes 8.33×10^{-3} (3 sig fig). The large number 19878956 would become 1.99×10^{7} (3 sig fig).
- This powerful form of scientific numbering is used throughout science, especially when small amounts of materials are used.
- To put the number into standard form follow the simple steps below:

		Example 1	**Example 2**
(i)	Write out the number.	0.00833	19878956
(ii)	Place a decimal point between the first two non-zero parts of the number.	0.008•33	1•9878956
(iii)	Move toward the original decimal point noting the direction you move and *number* of jumps.	3 places left	7 places to the right
(iv)	Construct the number – if moving left, the power is *negative*, if moving right the power is *positive*.	8.33×10^{-3}	1.9878956×10^{7}
(v)	Round to three significant figures	8.33×10^{-3}	1.99×10^{7}

Percentages

- Percent means *out of 100,* and fractions or decimals are converted to percentages by simply multiplying them by 100.
- It's effective as our brains most easily use numbers between 1 and 100.
- Conversion of fractions or decimals into percentages allows an instant *comparison* which carries *meaning.*
- For example, would you choose to smoke if I said that 90% of all smokers died of lung cancer before age 60? What if I said that 1% died instead? Your brain can easily process and use these figures to make reasoned judgements.

Ratios

- Fractions can also be considered to be ratios.
- A ratio maintains a constant relationship between the top and bottom numbers of the fraction.
- A fraction of $\frac{1}{10}$ can translate as *one in ten.* So if *one in ten* students get a grade A, then by scaling the numbers by equal amounts on the top and bottom can give an appropriate expectation of other combinations of numbers. For example of $\frac{1}{10}$ is the same ratio as $\frac{2}{20}$ or $\frac{8}{80}$. So I could reasonably expect 6 grade A results out of a group of 60 students.

Powers and exponents

- When a number is raised to a power, for example 2^4 it means that the 2 is multiplied by *itself*, four times (2 x 2 x 2 x 2 = 16).
- On a calculator this is achieved using the $\boxed{x^n}$ or equivalent button.
- This calculation can be done by pressing 2 $\boxed{x^n}$ 4 $\boxed{=}$
- For standard form, scientific calculators have a function which multiplies the value by the 10^x. The $\boxed{x10^x}$ or $\boxed{exp}$ buttons will automatically put that part of the standard form in place. So pressing 1.99 $\boxed{x10^x}$ 7 will enter $1.99x10^7$ into the calculator.

Logarithms

- Taking a logarithm, or *log* of a number, is a mathematical transformation that scientists use to compress data that are spread over a wide range, again to make the numbers more manageable and comparable.
- On a calculator simply type $\boxed{log}$ followed by the number you wish to log.
- So the log of 2.99 is found by typing $\boxed{log}$ 2.99 $\boxed{=}$ which gives 0.476.
- A logarithm can be converted back to the original number by using the *antilog* function, or $\boxed{shift}$ $\boxed{log}$ 0.476 $\boxed{=}$ which gives 2.99.

Handling Data

Much of the data handling in AS biology is in the form of graphs and their interpretation. With this in mind much of the graphical content outlined in the minimum requirement under **Handling Data** has been included in the Graphs section.

Some of the contexts in which these data manipulations are used are expanded further in the **How Science Works** section.

Rounding

- When a decimal number is rounded, it loses some of its precision and can therefore introduce some inaccuracies in calculations if not handled appropriately.
- To round the number *up* or *down* follow the simple steps below:

		1 dp	**2dp**	**3 dp**
(i)	Write out the original number and decide on how many decimal places you need. e.g. 2.849 to 2dp.	2.8494	2.8494	2.8494
(ii)	Decide whether the figures after number of decimal places you want is less than or greater than 5xxx	2.8***494*** Where 494 is *less than* 500	2.84***94*** Where 94 is *greater than* 50	2.849***4*** Where 4 is *less than* 5
(iii)	If it is *less than*; then remove the extra decimal places,	2.8		2.849
(iv)	If it is *greater than*; then increase the last digit remaining by 1		2.85	

- In practice rounding is a lot easier to *do* than it is to *describe*!
- It is advisable only to round your answer *up* or *down* to the appropriate number of decimal places **at the end** of a calculation to minimise the risk of errors creeping in along the way.
- In general, rounding is a simple technique but the number of decimal places that you round to will vary depending on the *size*, or *magnitude* of the number. It is easier to use **three significant figures** as the appropriate level of precision for many situations if the number of decimal places is not specified (see below).

Significant figures

- In biology the use of significant figures tends to be preferable to decimal places. This is because different numbers have different *magnitudes*, or sizes. A good example of this is money. If you had £1,000,000 pounds in your bank account, it would barely seem relevant whether it was £1,000,000.01 or £1,000,000.99.

- Like rounding, showing you how a number can be expressed to a certain number of significant figures is easier to *do* than to describe. There are a few rules to assigning significant figures:

(i) All non-zero numbers are significant (e.g. 9700 has 2 significant numbers, 9 and 7.

(ii) Zeros appearing between two other digits are significant (e.g. 101 has three significant figures, 1, 0 and 1.

(iii) Leading zeroes are not significant (e.g. 0.0052 has 2 significant figures 5 and 2).

(iv) Trailing zeros of a number before a decimal point are significant (e.g. 91200.1 has 6 significant figures 9, 1, 2, 0, 0 and 1).

(v) If appropriate, a number can be rounded up or down (e.g. 512 to two significant figures is 510 whereas 587 to two significant figures is 590.

Examples:

907.459	0.000528715	have 6 sig fig
907.46	0.00052872	have 5 sig fig
907.5	0.0005287	have 4 sig fig
907	0.000529	have 3 sig fig
910	0.00053	have 2 sig fig
900	0.0005	have 1 sig fig

Graphs

A graph is a diagrammatic means of representing the relationship between two variables. There are many types of graph, such as line, scatter, pie, histogram some of which you should probably be familiar with.

In biology, line graphs are one of the most important types you will meet and much of your practical work will look at how a *dependent variable* (shown on the *y-axis*), changes as the *independent variable* (shown on the *x-axis*) changes.

Plotting graphs

When a graph is plotted there are a number of rules you need to follow:

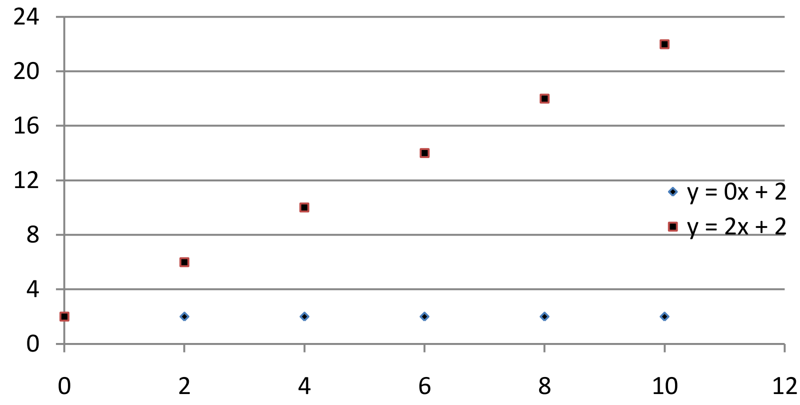
- ✓ Use as much of the graph paper as possible.
- ✓ The dependent variable (e.g. colour, rate, volume, mass etc.) is placed on the vertical (*y*-) axis. If in doubt this is usually the *thing* you are *measuring*.
- ✓ The independent variable (e.g. time, concentration) is placed on the horizontal axis (*x*-) axis. If in doubt this is usually the *thing* you are *changing*.
- ✓ You must always label the axis stating clearly what the variable is and give its unit e.g. time (s) or mass (g).

Linear relationships

In maths, a linear relationship can be described by the equation $y = mx + c$ where m is the *gradient*, the slope of the line and c is the *intercept*, the point at which the line crosses the *y-axis* when x = 0. Consider the table of data below:

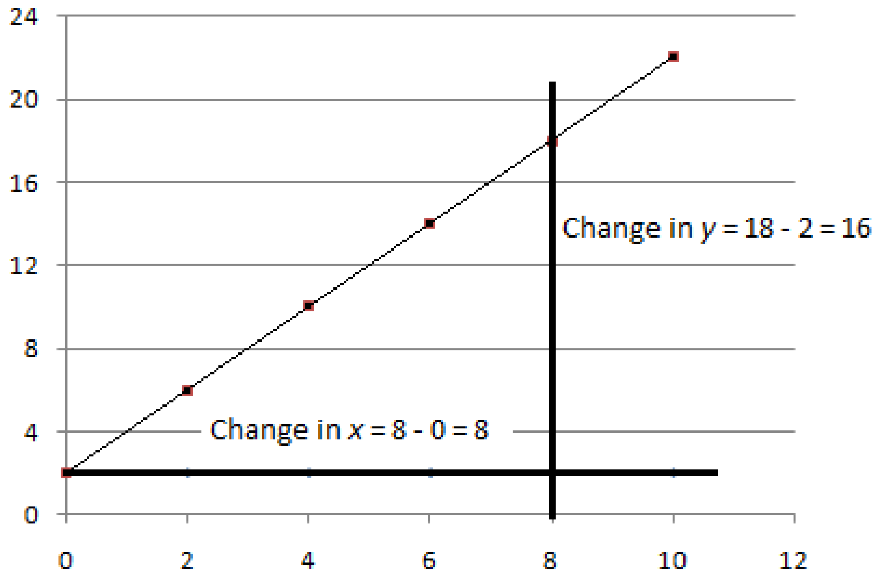
x	y = 0 x + 2	y = 2x + 2
0	2	2
2	2	6
4	2	10
6	2	14
8	2	18
10	2	22

When the data are plotted the following two graphs are obtained. Fitting a straight *line of best fit* through the data would show that when x = 0, y = 2 in both cases, hence the intercept, c = 2.



The *gradient* of the line, the value of *m*, can be found by using the equation:

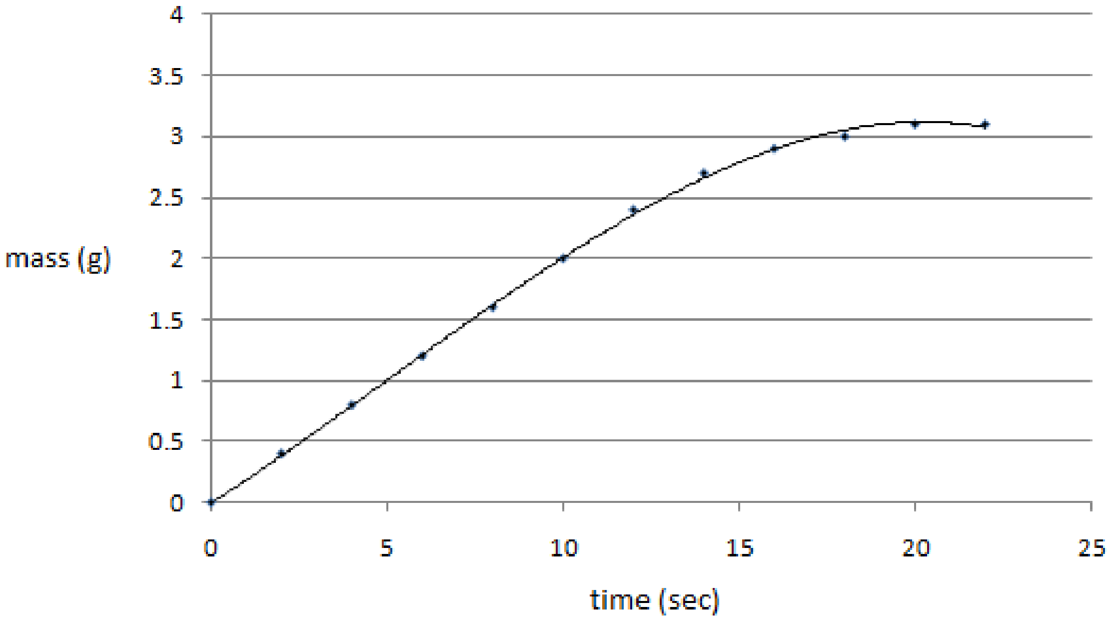
$$Gradient = \frac{change\ in\ y}{change\ in\ x}$$



For linear relationships this can be found from the graph as shown below:

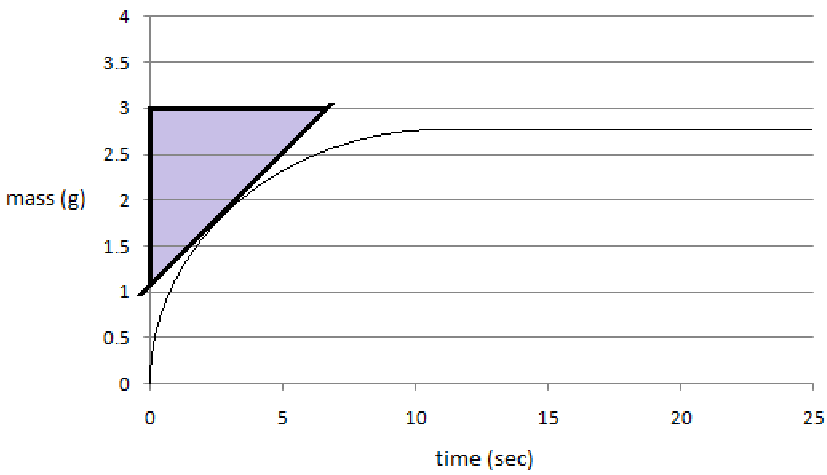
- From low down on the y-axis where the *line of best fit* crosses, draw a *horizontal* line across the page.
- Draw a *vertical line* up from the x-axis to cross your horizontal line and the *line of best fit.*
- It is always best to use the lines across that use up more than half the graph paper, in order to get the most precise estimate of the gradient.
- Calculate the difference in the points at which the lines cross the *line of best fit*, both vertically (the change in y) and horizontally (the change in x). This is shown on the graph below.
- The gradient is then found using the equation above.

In enzyme reactions, the *rate of reaction* can be determined experimentally using this method. When a graph of, for example, mass of product formed is plotted against time, the gradient of the relationship at any given time is the reaction rate (expressed in *g per second*, or g sec^{-1} in this case).



Notice that at first there is a straight line relationship between mass and time, so the mass of product formed α (is proportional to) time. As the reaction proceeds towards completion the graph starts to tail off and become flat.

If the rate of reaction is needed at a given point on this *shoulder* region, it can be found by drawing a tangent to the curve and determining *its* gradient. A tangent is a straight line or plane that touches a curve or curved surface at a point but does not intersect it at that point. Calculation of the gradient of the tangent by using the method outlined above will give the rate of reaction.



Frequency tables, pie charts, bar charts and histograms

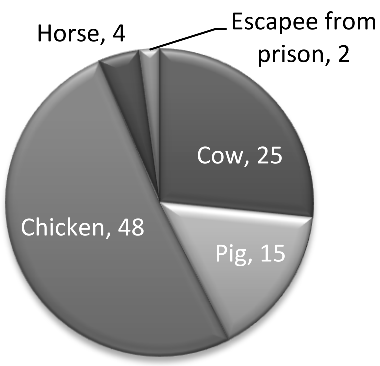
A *frequency table*, or *tally chart* is a means of collecting and organising data into discrete groups. The data is then often presented as a *bar chart* or *histogram*. Tally charts for sampling biological data usually have two or more columns, the first of which is for recording the *independent variable*. If the independent variable can be numbered (like a weight, height etc) it is quantitative), if cannot be numbered it is said to be qualitative (like brown eyes, blue eyes etc).

Categoric data

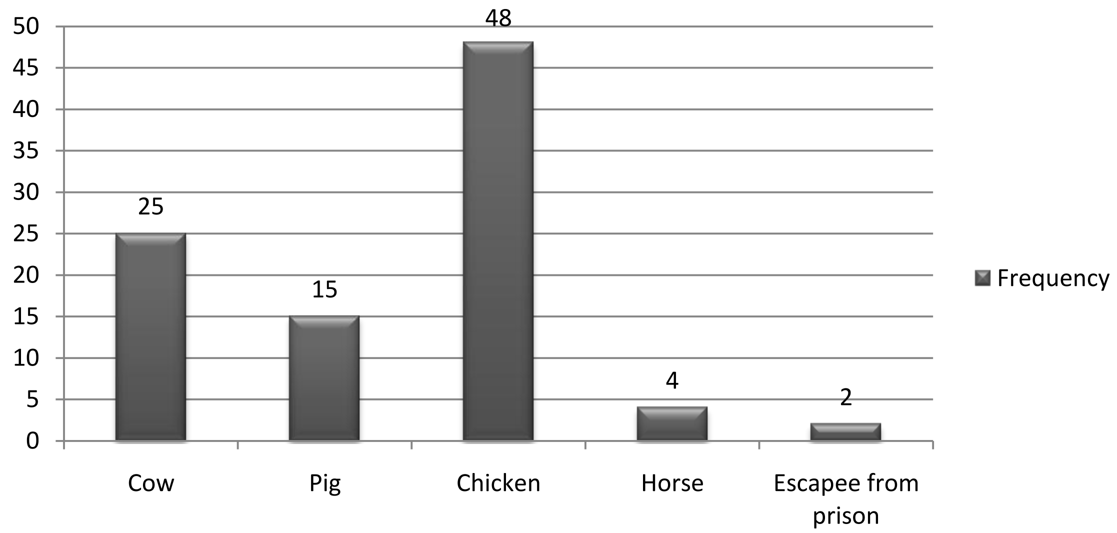
If we were to make a frequency table for animals in a farmer's field we might list the different animals in the first column and tally the number (or *frequency*) of that animal in the second column. Because the animals fall into different categories that do not overlap, the data is said to be categoric and discontinuous. As they aren't numbers, the data is said to be qualitative.

Animal	Frequency
Cow	25
Pig	15
Chicken	48
Horse	4
Escapee from prison	2

Such data can be presented on a pie or bar chart. The pie chart represents the total number of animals as 100%, and is the entire 360^0 of the circle. Each variable is then attributed a *slice* of the pie whose size is proportional to the frequency, so the more it is then the bigger the slice. In the example below, 48 out of 94 animals are chickens and so their slice of the pie is just over a half at 51%, or 183.8^0 and so on for the rest of the animals.



The same data is presented below, but as an unranked bar chart. This time, the area of their rectangular bar is proportional to the number of animals in each category.



These kinds of chart are useful for presenting data sampled for discontinuous variables, but sometimes the data is *continuous*. In such cases a histogram is a better option.

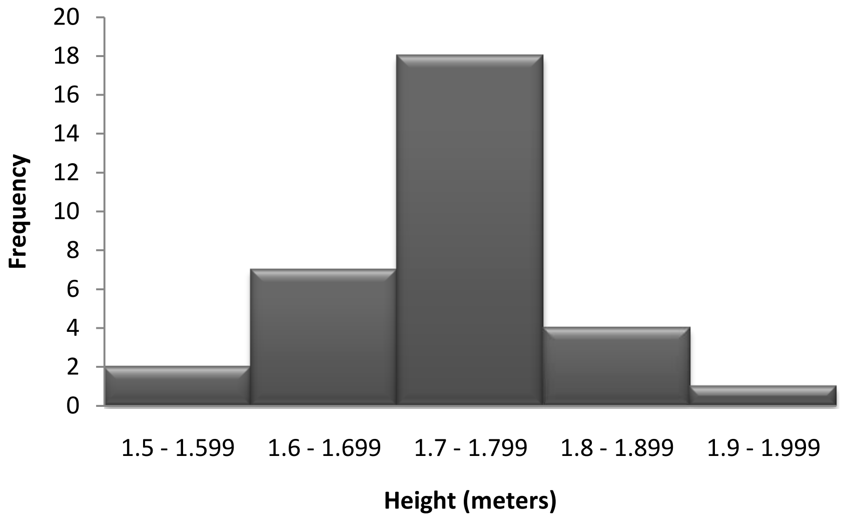
Continuous data

For variables such as height or weight that show a *quantifiable* change (a change you can put a number to) the frequency table can be used to produce a histogram. Consider the following table showing a *distribution* of the number of male students and their heights in a class of AS biology students.

Height	Frequency
1.5 - 1.599	2
1.6 - 1.699	7
1.7 - 1.799	18
1.8 - 1.899	4
1.9 - 1.999	1

The independent variable now reflects a change in the heights of the students from 1.5 meters up to 2 meters and the number of students falling to specified height groups are tallied and counted. The "bar chart" formed is now termed a histogram and the data shows the distribution of heights in the student's class.

This type of bell-shaped curve is called a *normal distribution* curve and forms the basis of some slightly more complex statistical testing which you will tackle later in the A2.



If you were to imagine and visualise this data, you would see that "most" students are of average height with one very tall and two very short class members. It is this ability to visualise a distribution in different ways which makes this kind of data presentation a powerful tool in biology.

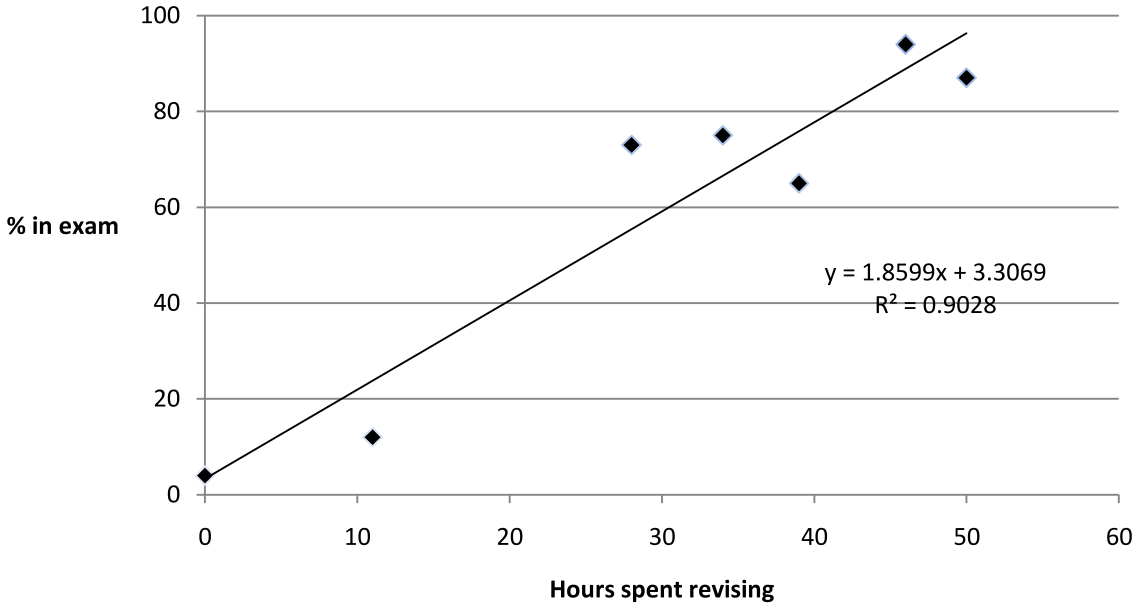
Scatter diagrams

Scatter diagrams allow a quick and easy means to visualise a relationship between two sets of numerical data that are paired in some way. They follow a similar principle to the line graph, except a line or curve does not connect each successive point; rather the eye is drawn towards the overall trend being shown.

Consider the following pairs of data which show the relationship between the number of hours a group of seven students revised for an exam and the percentage marks they received:

Time spent revising	% in exams
0	4
50	87
46	94
11	12
34	75
28	73
39	65

As the hypothesis of the study was to show that the more hours revising would get a better grade, then the time spent revising was considered to be the independent variable. The data are then arranged on a scatter diagram as a series of x , y (independent , dependent) pairs of data.



A line of best fit can be calculated and placed through the data to further analyse the relationship between the two variables. If the line goes up, there is a positive correlation (so the more hours spent revising, the better the result). If the line goes down then there is a negative or inverse correlation between the variables.

The gradient of the line, *m* and the intercept, *c* can be used to predict what grade a student might expect for a given number of hours spent revising. Using the equation y = m*x* + c in the above example might suggest a student who worked for 20 hours might expect a (1.86 x 20) + 3.3 = 40.5% in the exams. But because of the scatter around this line there is a degree of uncertainty around this estimate.

The more data points there are then the more reliable is the interpretation of the relationship. In this case there are way too few points to draw a valid conclusion, but the general pattern is clear.

The investigators would aim to collect more data to see if the relationship held true in many more situations. The data could also be made more reliable by filling in the missing data around the 15 to 25 hour mark. Later on you will learn that this type of association between two variables can be tested to determine its statistical significance.

Algebra

Symbols

You are required to know the meaning and context of the following symbols. A *translation* is included to show how the mathematics can be interpreted. These symbols may appear in algebraic expressions or be used in text or summaries in chemistry. Some examples are given below.

Symbol	Translation	Example of context
=	Is equal to	The mass of a shrew = 25 g
<	Is less (or lower than) than	The mass of a horse < cow
<<	Is much less than	The mass of a shrew << elephant
>	Is greater than	Temperature effects > mass effects
>>	Is much greater than	Chance of catching flu >> developing cancer
α	Is proportional to	The rate of reaction α concentration
~	Is approximately equal to	Biodiversity index of field 1 ~ of field 2
Σ	Sum of	Total eggs = Σ eggs laid by each hen
%	Percent (or *out of 100*)	On average 30% of the day is spent asleep

Rearranging equations

Incorrect equation rearrangements, or changing the subject of an equation as it is known, accounts for a large percentage of mathematical errors in biology exams. It's a skill that many science teachers expect their students to have already and so they do not show them simple ways of doing it.

There are several rearrangement methods, all of which result in the same rearrangements if done properly. Two have been included here for you to choose from. I suggest you practice both and use the one that gives to the correct answer most of the time.

For Equations involving multiplication and division:

Method 1: Rearrangement

In biology the rearrangement of equations such as

$$magnification = \frac{image\ size}{actual\ size}$$

are common expectations in exams. You can rearrange these types quickly by applying the following steps.

For example; **to make *image size* the subject of the equation**:

(i) Focus on the *subject*, the variable you want to find, e.g. *image size*.
(ii) Whatever another variable is doing **to** the *subject*, then **do the opposite** to it (divide if it's multiplying, multiply if it's dividing), on **both sides** of the equation. This means:

$$\boldsymbol{actual\ size} \times magnification = \boldsymbol{actual\ size} \times \frac{image\ size}{actual\ size}$$

(iii) As anything divided by itself = 1, then the above cancels down to:

$$\boldsymbol{actual\ size} \times magnification = \cancel{\boldsymbol{actual\ size}} \times \frac{image\ size}{\cancel{actual\ size}}$$

$$actual\ size \times magnification = image\ size$$

For example; **to make *actual size* the subject of the equation**:

(i) If the *variable* you want to make the *subject* of the equation is currently underneath another one, then **first of all** multiply both sides by it. This means:

$$\boldsymbol{actual\ size} \times magnification = \frac{\boldsymbol{actual\ size} \times image\ size}{actual\ size}$$

(ii) Cancel this down to get a linear equation:

$$\boldsymbol{actual\ size} \times magnification = \frac{\cancel{\boldsymbol{actual\ size}} \times image\ size}{\cancel{actual\ size}}$$

$$actual\ size \times magnification = image\ size$$

(iii) Repeat step (ii) but this time divide both sides by magnification, so:

$$\frac{actual\ size \times magnification}{\boldsymbol{magnification}} = \frac{image\ size}{\boldsymbol{magnification}}$$

(iv) Cancelling this down gives the rearranged equation:

$$\frac{actual\ size \times \cancel{magnification}}{\cancel{\boldsymbol{magnification}}} = \frac{image\ size}{\boldsymbol{magnification}}$$

$$actual\ size = \frac{image\ size}{magnification}$$

Method 2: Linearised method

This method is simpler, but it requires you to **learn** the *linearised* versions of the equations first. All you do is **learn** a linear version and then just *put everything except the subject under the other side of the equation*. It's that simple! Using the above example, a linear version of the equation would be:

Image size = actual size x *magnification*

Common *linearised* equations you will need for AS biology include:

- ✓ *Image size = actual size* x *magnification*
- ✓ *Volume = length* x *breadth* x *height*
- ✓ *distance = rate* x time
- ✓ *Number of bases on DNA = number of amino acids* x *3*
- ✓ *Cardiac output = stroke volume* x *heart rate*
- ✓ *Pulmonary ventilation = breathing rate* x *tidal volume*

For equations involving addition and subtraction:

The principles involved in rearranging equations with addition or subtraction is the same as for multiplication in *Method 1* above. If the variable you want to make the subject is *positive* then do the *opposite* function (addition or subtraction) for *all* other variables, *on both sides*. For example, to make Ψ_s the subject from the equation $\Psi_{cell} = \Psi_s + \Psi_p$:

(i) $\Psi_{cell} \mathbf{-\ \Psi_p} = \Psi_s + \Psi_p \mathbf{-\ \Psi_p}$
(ii) Which simplifies to $\Psi_{cell} \mathbf{-\ \Psi_p} = \Psi_s$
(iii) Repeat the process with any other variables present

If the variable you want to make the subject is *negative* then start by adding that variable to both sides and then repeating the process outlined above. For example, to make Ψ_p the subject from the equation $\Psi_s = \Psi_{cell} - \Psi_p$:

(i) $\Psi_s \mathbf{+\ \Psi_p} = \Psi_{cell} - \Psi_p \mathbf{+\ \Psi_p}$
(ii) Which simplifies to $\Psi_s \mathbf{+\ \Psi_p} = \Psi_{cell}$
(iii) $\Psi_s \mathbf{-\ \Psi_s} + \Psi_p = \Psi_{cell} \mathbf{-\ \Psi_s}$
(iv) Hence, $\Psi_p = \Psi_{cell} - \Psi_s$
(v) Repeat the process with any other variables present

You are most likely to meet these rearrangements under the *osmosis* section of your specification.

✓ $\Psi_{cell} = \Psi_s + \Psi_p$

Conversion of Units

SI Units

A physical unit gives a sense of scale to a value and allows comparison of different numbers. As long as, e.g., I know the *gram* is smaller than a *kilogram*, then I know that 20 g of glucose represents a *much lower* mass than 20 kg. This may be an obvious point but it never ceases to amaze me how many students completely disregard units and their inter-conversions.

As a general rule of thumb, if the examiners do not ask for a unit then it is best *not* to stipulate one. This is because in mark schemes a correct unit is often seen as neutral whereas an incorrect one can be penalised. This said, many calculations in biology *do* require you to interconvert between units and do clearly specify that you should include a suitable unit in your answer.

As there are so many different units of physical parameters such as temperature, mass, amount, length, volume, pressure etc., the scientific community uses an International Standard (*SI*) unit. Smaller or larger subunits extend out from this, usually in factors of 1000. On the table below, the units in **bold** type are the commonest ones for that parameter that you will use at AS level.

$1x10^{-6}$	$1x10^{-3}$	SI unit	$1x10^{3}$	$1x10^{6}$
Milligram (mg)	**gram (g)**	Kilogram (kg)	Tonne	
Micromole (µmol)	Millimole (mmol)	**Mole (mol)**		
Centimetre cubed (cm^3)	**Decimetre cubed (dm^3)**	Meters cubed (m^3)		
		Pascals (Pa)	**Kilopascals (kPa)**	Megapascals (MPa)

If you are converting units from **left → right**, then multiply by the number by $1x10^{-3}$ (**which is the same thing** as saying d*ivide* by 1000) for each box covered. So, e.g., 20 mg = $20x10^{-3}$ g = $20x10^{-6}$ kg etc.

If you are converting units from **right → left**, then multiply by $1x10^{3}$ (**or** *times* by 1000) for each box covered. So e.g., 3 tonnes = 3000 kg = 3,000,000 g.

For *temperature*, the SI unit is the Kelvin, *K*. The *Celsius* scale is 273^0 lower than this so:

- ✓ To convert Celsius to Kelvin, *add* 273 to the ^{0}C; 25^0C is 298 K
- ✓ To convert Kelvin to Celsius, *subtract* 273 from the K; 0K = -273^0C.

Absolutes and concentrations

It is important to distinguish between *absolutes* and *concentrations*. An *absolute* is a physical amount of material, be it 10 g of glucose or 25 dm^3 of carbon dioxide. On the other hand, a concentration represents a certain *amount* of a substance *in a stated volume*. The *molar concentration* is expressed in mol dm^{-3}, the same as saying *moles per decimetre cubed,* or *molarity, M*. So a 1 mol dm^{-3} solution of glucose contains one mole of glucose dissolved in every decimetre cubed of solution.

In many of the questions you will face, especially those in practicals, you will have to apply the process of *proportions* to convert a concentration to an absolute or *vice versa*. For example, if there is 1 mole of glucose per decimetre cubed (1000 cm^3) then there is 0.5 mol in 500 cm^3 or 0.1 mol in 100 cm^3.

Geometry

Two dimensional objects

The formulas for calculating the areas and volumes of common shapes are shown here to get you familiar with them. You **will not be expected** to **recall** them, but you **will be expected** to be able to **use** them.

The area of a square (or rectangle) is found by multiplying its length by its height and its unit will be mm^2, cm^2 or m^2 depending on the unit of measurement used:

$$area\ of\ a\ square\ (rectangle)\ = length \times height$$

The circumference (the *distance around*) of a circle is found by multiplying π by its diameter (the *distance across* the centre) and its unit will be mm, cm or m depending on the unit of measurement used.

$$circumference\ a\ circle\ = \pi \times diameter$$

The area of a circle is found by multiplying π by its radius (the *distance from the centre of the circle to its edge*, or *half the diameter*) squared and its unit will be mm^2, cm^2 or m^2 depending on the unit of measurement used:

$$area\ of\ a\ circle\ = \pi \times radius^2$$

Three dimensional objects

Most objects in biology are considered to be three dimensional. Even a leaf has a finite thickness and is not flat. You will learn during your studies that the surface area of a cell or organism is an important factor that determines its ability to exchange gases or water. Being able to calculate surface areas and/or volumes of three dimensional objects such as cubes and cylinders can help to provide models to understand adaptations that some organisms have to assist their gas exchange processes.

Volume and surface area of a cube

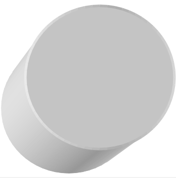
A cube is essentially a three dimensional square and as such it occupies a certain volume of space. This volume (in mm^3, cm^3, m^3) is found by multiplying its length by its breadth and height.

$$volume\ of\ a\ cube = length \text{ x } breadth \text{ x } height$$

The cube is composed of six faces, each of which is a square that has an area that can be found by multiplying its length by its height. It follows then that the total surface area of the cube is the sum of the areas of each face.

$$surface\ area\ of\ a\ cube = \Sigma\ areas\ of\ each\ face$$

Volume and surface area of a cylinder



A cylinder is essentially a circle that has thickness and so it occupies a volume of space. This volume (in mm^3, cm^3, m^3) is found by multiplying the area of its circular end by its height.

$$volume\ of\ a\ cylinder = area\ of\ its\ circular\ end \text{ x } height$$

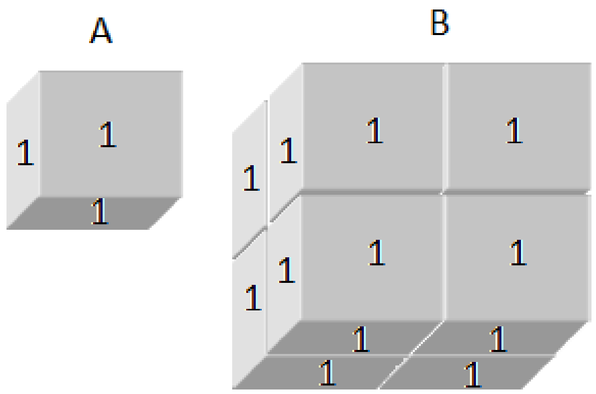
The cylinder is composed of two circular ends, each of which is a circle that has an area that can be found by multiplying π by its radius². The central bar of the cylinder can be thought of as a rectangle whose length is the height of the cylinder and whose height is the circumference of the circular end. It follows then that the total surface area of the cylinder is the sum of the areas of each face and can be given by the following gobbledegook:

$$surface\ area\ of\ a\ cylinder = 2 \text{ x } \pi\ x\ radius^2\ x\ height \text{ x } \pi \text{ x } diameter$$

Surface area to volume ratio

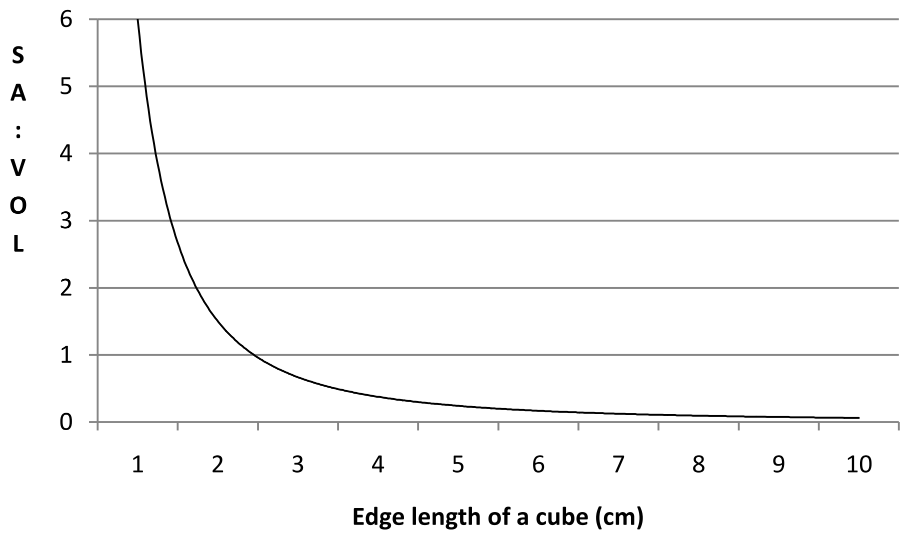
While the volume and surface area of an organism are important, it is the ratio of the surface area to the volume (SA:VOL) that is the key to understanding biological adaptations for gas exchange.

As an organism gets bigger, its volume increases as does its surface area. That makes complete sense, but what disturbs many students is the fact that the SA:VOL gets **smaller** as the organisms gets **bigger**. This is best shown mathematically. Consider cubes A and B below.

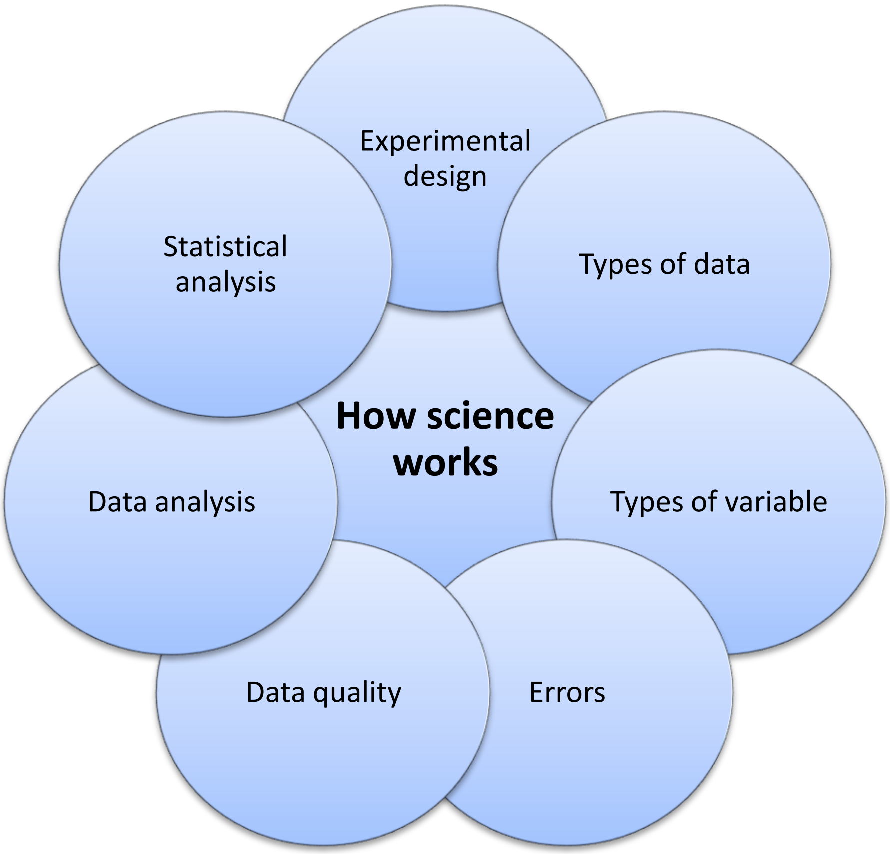


Cube A has a surface area of 6 cm^2 (six faces each having a 1 cm^2 area). Its volume is 1 cm^3 so its SA:VOL = 6 ÷ 1 = 6. **Cube B** has a surface area of 24 cm^2 (six faces each having a 4 cm^2 area). Its volume is 8 cm^3 so its SA:VOL = 24 ÷ 8 = 3.

The tendency for SA:VOL ratio to decrease as size increases is shown below for other cubes. This trend is mirrored in other shapes as well but the cube is a simple model to understand and apply.



How science works

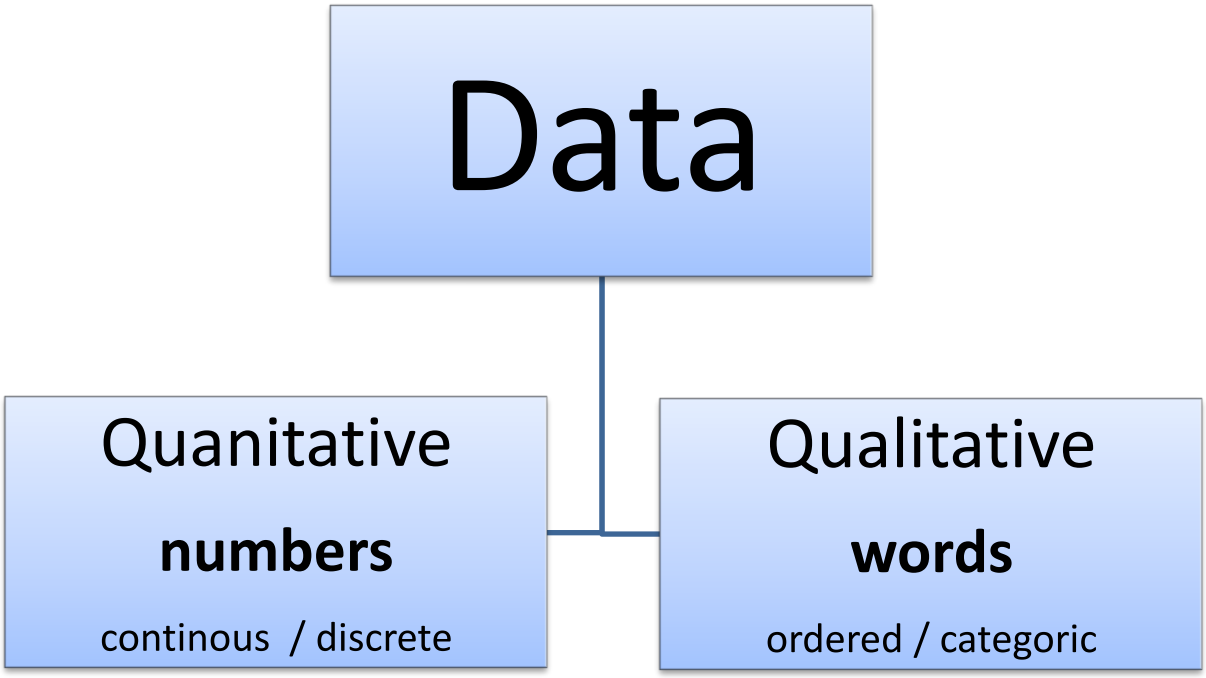


In the dreaded *How Science Works* aspect to the specification, you will need to be familiar with many aspects of studies and study design. The diagram above tries to separate out these different aspects while at the same time suggesting how they are all interconnected and exert an impact on one other. For example, a study that is poorly designed would yield low quality data with many errors that would confound the analysis and impair the statistical significance of the result and ultimately lead to an invalid conclusion.

A discussion of these aspects in relation to the mathematics of data handling is included here to help you familiarise yourself with the ways in which these aspects impact on the maths questions you will face. A glossary of *How Science Works* terms is included at the back of this book to help you keep on top of the different terms.

Types of data

Data are measurements taken in an experiment or study. There are essentially two types; quantitative (numerical) or qualitative (words). Quantitative data can be continuous (take any value in a range, e.g. height) or discrete (discontinuous, e.g. the number of bands on a snake or spots on a ladybird) whereas qualitative data can be ranked (ordered, e.g. small, medium or large) or unranked (categoric, e.g. spotted, striped, plain).

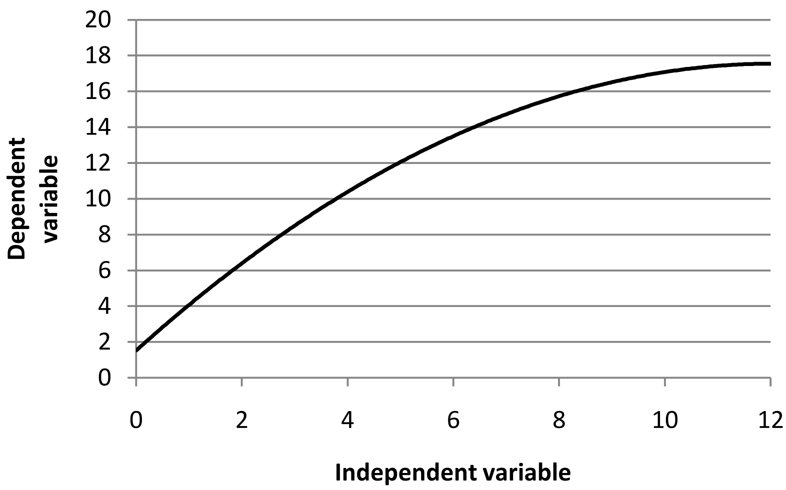


The best ways to plot or present the data depends to some degree on the type. Categoric data suits pie or bar charts best whereas continuous data suits histograms. Other suitable examples are included further in this book.

Types of variable

Dependent and independent variables

In a study, the *independent variable* (plotted on the x-axis) is changed under controlled conditions. Measurements are then taken to see how the *dependent variable* (plotted on y-axis) is affected by that change. So for example, we may want to see how the rate of oxygen production from liver is affected by increasing the concentration of hydrogen peroxide. In this case the independent variable is the concentration of hydrogen peroxide (x-axis) and the volume of oxygen measured is the dependent variable (y-axis) as the volume of oxygen formed ultimately depends on the hydrogen peroxide concentration.



Confounding and control variables

Confounding variables are variables that also affect the dependent variable (e.g. temperature or enzyme concentration in the example above). If a test is to be declared fair then all the confounding variables must be kept constant and controlled, e.g. a fixed temperature or amount of liver. If it is not possible to control the variable, for example the amount of water in soil during a field test, then they should be monitored closely to assist the analysis and interpretation of the data. A *control variable* in a study is a confounding variable that is kept constant.

Data quality

The quality of the data generated will impact severely on the analysis and interpretation of the results. Included below is a list of terms that you will come across time and again. Each term must be internalised and used in its correct context as these terms are *not* interchangeable.

True value

The real value of a measurement, if it could be recorded with no errors.

Accurate data

A measurement that is as close to the true value as the precision allows.

Precise data

Measurements that give similar values if repeated and so have a narrow range. Data that are generated using sensitive equipment with a suitable scale will generate more precise values (e.g. a thermocouple capable of detecting 0.05^0C intervals is more precise than a thermometer that can detect 1^0C differences in temperature).

Reliable

Findings that can be repeated are said to be reliable. Consider a bus which arrives at 8:01am each day to take you to college would be a reliable service. One which came randomly between 7:45am and 8:25am would be unreliable as it did not *repeat* consistently.

Valid data

This is the best quality data as it is both precise and reliable and obtained by unbiased means in a controlled experiment. In this regard it can be assumed to be accurate.

Errors

Errors are intrinsic to any study in the real world. They cause the value of the measurement to vary away from the true or accurate value. There are a number of different types:

Random

These are errors that creep into a study due to inaccuracies, mistakes or poor techniques. The impact of random errors on the overall results can be lessened by talking many repeats.

Systematic

These are errors which take place *in one direction*. For example, if a balance was not calibrated correctly to 10 g and was 1 g too high, then a 10 g weight would read 11 g and a 20 g weight would read 21 g etc. Systematic errors are intrinsic to the system and cannot be improved by repetition.

Zero

A zero error is a kind of systematic error that results when an instrument, e.g. a balance does not return to zero after the measurement.

Bias

Bias occurs when the operator chooses a certain type of result and ignores others. If, for example the operator had pre-decided that a certain area of ground had more plants than another, he might sample those parts that had the greatest density of plants by site as if to *prove the point*. Bias can be removed by random sampling which will be discussed in the next section.

Anomaly (outlier)

During most investigations some data is generated that might be considered anomalous, or outlying. Due to biological variation it is often very difficult to identify whether an anomalous data point is due to an error or a consequence of variation. Large numbers of repeat measurements can help resolve this satisfactorily.

Sampling

Biological data has to be collected, or *sampled* in some way. The method by which the data is collected has a huge impact on the quality of the results, their reliability, precision, accuracy etc. This in turn will impact on the validity of any conclusion that can be drawn.

In a real life situation it is impossible to count every organism or collect every specimen of a species under investigation. You couldn't for example count every daisy in a field, even if you wanted to estimate their density. In such cases a sample of the population is taken and this is taken in such a way to ensure that the sample is representative of the population as a whole.

Let's say we wanted to estimate the population of daisies in a 100 m^2 field. When we look at the field, we notice that there are some areas of the field where there are lots of daisies and some where there are none. Say we decided to only take a measurement of daisies in regions where there were lots of flowers. This would *bias* the overall result because we have chosen certain area to suit our aims.

First of all, the only way to avoid bias is to *randomly* choose which area to take measurements. The area being sampled could be divided up into a grid and a number assigned to each grid. A random number generator or table can then be used to help choose which grid areas are sampled. Secondly, we now face another problem. How many grids should we sample? If we only sampled one, and that happened to fall on an area very rich or very poor in daisies, our results would be inaccurate. But if we sampled too many we would be there all day and we run the risk of causing damage to the habitat we are studying. Choosing a compromise of about ten grids allows us to generate data that is reliable enough to draw a valid conclusion.

By having these repeated measurements, we would then be able to analyse the data and perform a statistical analysis to help us assess the significance of the results we have found.

Data analysis

Once the data has been sampled it can be transformed, manipulated and summarised to help us view it in such as way as to draw conclusions. Often the first step is to calculate an average of the data (mean, mode or median) and to look at the range, or standard deviation in the data.

Means, modes and medians are all types of average, but each one can give a different value. One type of average may be more appropriate than another in different contexts. In AS biology the most common type of average is the mean, but you must also be aware of how the others are calculated.

Consider the list of data; 1, 2, 2, 3, 4, 7, 9. Using this simple data set shows the differences in the values that can be obtained. The arithmetic mean would be 4, the median is 3 and the mode is 2. How each is calculated is shown below.

Arithmetic Mean

A mean is one of three kinds of mathematical average (mode and median are others). The mean is found using the equation:

$$Mean = \frac{\Sigma\ values\ being\ avaeraged}{number\ of\ values\ to\ be\ averaged}$$

Most people use the principle, "*add them all up and divide by how many there are.*" For example to find the average of 1, 2, 2, 3, 4, 7, and 9 the equation is used:

$$Mean = \frac{1+2+2+3+4+7+9}{7} = \mathbf{4}$$

> One common error is to **fail to check** that the average value calculated lies **within** the range of the numbers being averaged. So in the example above 4 does lie between 1 and 9.

Mode

The *mode* is the most *frequent* number in a set of data, or the most likely value to be sampled. So in the set 1, 2, 2, 3, 4, 7, 9, the number **2** appears more times than the others and so that is the mode of this data set.

Median

The median is the value that separates the higher half of the sample from the lower half. This is found by placing the data in a rank of increasing numbers; 1, 2, 2, **3**, 4, 7, 9. As there is an odd number of data points, the number at the *central position* is the median. In this case it is the number **3**, at the fourth position as there are three numbers smaller, and three numbers higher than it.

For even data sets, there are two central numbers and the median is the average of those two numbers. For example, if the data set was 1, 2, 2, **2**, **3**, 4, 7, 9 then the central two numbers are 2 and 3 and so the median would be the average of 2 and 3, which is **2.5**.

Determine the mean, mode and median of the following data set;

10, 15, 18, 7, 7, 14, 5.

$$\text{Mean } = \frac{10 + 15 + 18 + 7 + 7 + 14 + 5}{7} = \mathbf{10.9}\ (3sf)$$

$$\text{Mode} = \text{most frequent number} = \underline{7}$$

Median

(i) rank the data; 5, 7 , 7, <u>10</u>, 14, 15, 18

(ii) = select the central value = <u>10</u> (three lower, and three higher values)

Range

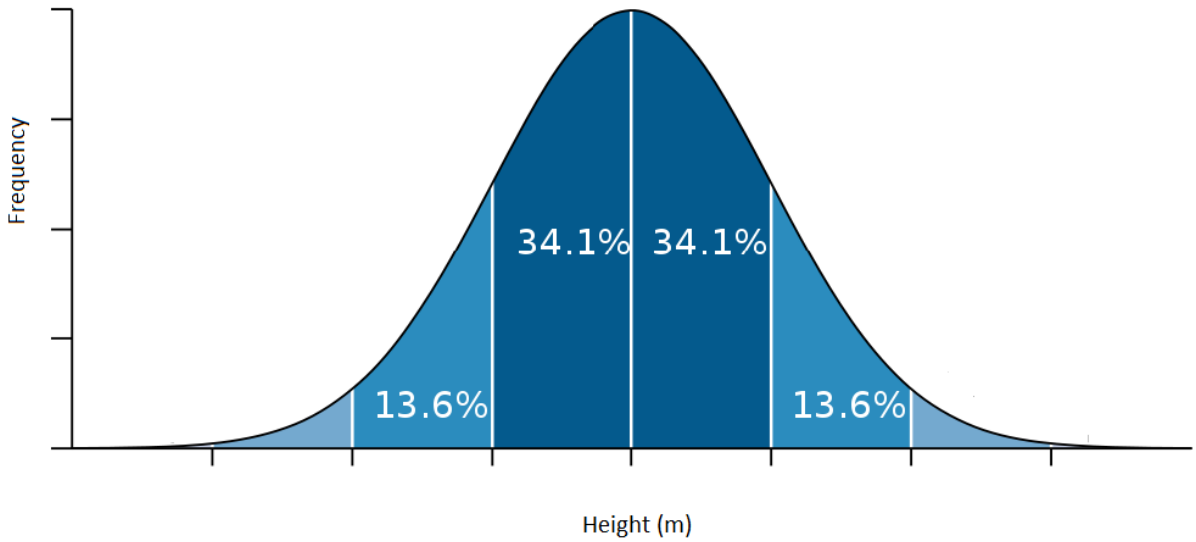
The range of the data is essentially the difference between the top and bottom values of the ranked data. In the data set from the section above (1, 2, 2, 3, 4, 7, 9) the data *ranges* from 1 to 9. So if we were to consider the range of heights of male students in an AS biology class, they may range from 1.5 to 1.99 meters; a *span* of 0.49 meters.

Standard deviation

The range may give an accurate indication of the top and bottom values in a set of data, but it does not reflect the spread of the data and the fact that most of these students *might* be between 1.6 and 1.68 with the rest being outliers.

The standard deviation is used as a better indication of the *spread* around the mean. It is a statistical concept that you'll learn how to calculate in A2 as part of the ISA/EMPA aspect of the specification. At this stage you do not need to know how to calculate it, but need to recognise that the bigger the standard deviation, the more spread the data.

In a normal distribution, the bell shaped curve, one standard deviation around the mean encompasses 68.2% of the data points around the mean value. Two standard deviations encompass 95.4% of the data points.



Put simply, about two thirds of the members of the class would have a height that lay within one standard deviation from the mean height. Such data is often expressed as *mean ± one standard deviation*. We might say the average height of male students in the class is 1.73 ± 0.2 meters. In this case we would know that 68%, about two thirds of the guys had a height between 1.53 (1.73 - 0.2) and 1.93 (1.73 + 0.2) meters.

Statistical analysis

When a study is designed, it is attempting to test a hypothesis and answer a particular question, or problem. A hypothesis can be defined as a possible explanation of a problem that can be tested experimentally. Generally at A-level there are three main types question you will attempt to answer using statistical tests (i) whether there is a difference between measurements of different samples using a **t-test**, **standard error** or **95% confidence intervals**, (ii) quantify a relationship between two variables using a **rank correlation**, or (iii) finding the number of individuals in certain categories and determine if their distributions are different using a **chi-squared** test.

Thankfully you'll not be expected to remember the formulae for the calculation but you will be expected to plug in the numbers for data in practical or ISA or EMPA questions.

Central to the idea of testing a hypothesis, is a **null hypothesis**. This is worded in terms of there being *no difference* or association between the two variables being compared (it's the negative version of a **hypothesis**). So if I wanted to test the hypothesis that the more hours I spend revising would get me a better exam result, I would need to test this against the null hypothesis that it would not.

Probability

The statistical tests generate **test statistic** which can then be used to help determine whether the event occurred by chance. The certainty of this is affected by the number of estimations or counts or measurements that were taken. It ought to be obvious that the more measurements we take then the more certain we should be of a certain result. These estimations are referred to statistically as the **degrees of freedom**. The greater the number of degrees of freedom, then the more certain we can be that an event was significant, and not due to a chance happening.

The test statistic and the degrees of freedom combine to determine the probability. **Probability** is the likelihood of an event occurring. It is different from *chance* because it can be expressed mathematically. When a statistical test is performed on data it generates a **p-value**. This is essentially an estimate of whether a finding is due to chance.

The probability of an absolutely impossible event happening is zero, 0. The probability an absolutely certain event happening is one, 1. Statistical tests generate values within this range. It is up to us as the investigators to decide an acceptable level of probability that an event is *not due to chance*.

A *p-value* of *0.05 of less* is generally considered by scientists to be *significant* as it means there is less than a 5% probability that the result was due to chance. In other words, if we were to do the investigation 100 times, 95 of them would generate data to support the hypothesis where five would support the null hypothesis, So a $p<0.05$ would mean that the null hypothesis is rejected and the result is deemed a *statistically significant* one.

End of Section 1 Test

Fractions, decimals, ratios and percentages

1. Express the following fractions as (i) percentages, (ii) decimals and (iii) standard form. Give all you answers to *three* significant figures:

   a. $\frac{5}{81}$ *(i)* % *(ii)* *(iii)*

   b. $\frac{4}{19}$ *(i)* % *(ii)* *(iii)*

   c. $\frac{1}{125}$ *(i)* % *(ii)* *(iii)*

2. In a recent college biology test it was shown that 18 of out every 57 students gained a grade B or above.

   a. Express this information as (i) a percentage, (ii) a decimal and (iii) in standard form. Give all your answers to three significant figures.

      (i) % *(ii)* *(iii)*

   b. Another teacher is setting the same test. How many students would he expect to achieve a grade B or above from a class of 36?

      ____

   c. Using the same test a third teacher found that four students gained grade B or above. How many students were in her class?

      ____

Score ______ / 14 [__________ %]

Powers and logs

3. Calculate the following:

   a. 4^5 ________ b. 2^3 ________ c. 3^7 ________ d. 4^2 ________

4. Determine the *logarithms* of the following *numbers*:

   a. 59 ________ (1dp)

   b. 7892 ________ (2 sig fig)

   c. 4.58×10^{-6} ________ (3 sig fig)

   d. 4^2 ________ (4 sig fig)

   e. 1.111 ________ (2 sig fig)

5. Determine the *numbers* of the following *logarithms*. Give your answers to the appropriate precision.

   a. 59 ________ (2 sig fig)

   b. -0.7892 ________ (4 sig fig)

   c. 4.58×10^{-6} ________ (1 sig fig)

   d. $4^{0.3}$ ________ (1 sig fig)

   e. 10.8 ________ (standard form)

Score ______ / 14 [__________ %]

Rearranging equations

6. By rearranging the equation $A \text{ x } B \text{ x } C = D \text{ x } E \text{ x } F$, make each of the following the subject of the equation:

   (i) A =

   (ii) C =

   (iii) D =

   (iv) E =

7. Rearrange the following equation

$$A = \frac{B \text{ x } C}{D \text{ x } E}$$

   (i) B =

   (ii) C =

   (iii) D =

   (iv) E =

8. By rearranging the equation $A + B - C = D + E - F$, make each of the following the subject of the equation:

   (i) A =

   (ii) B =

   (iii) C =

   (iv) E =

   (v) F =

9. Rearrange the following equation

$$A = \frac{B + C}{1000}$$

(i) B =

(ii) C =

(iii) 1000 =

Score ______ / 16 [__________ %]

Unit conversions

10. Express the following *masses* as the specified units:

a. 10 g = __________ kg
b. 802 mg = __________ kg
c. 145 kg = __________ g
d. 14 mg = __________ g

11. Express the following *volumes* as the units specified n the questions:

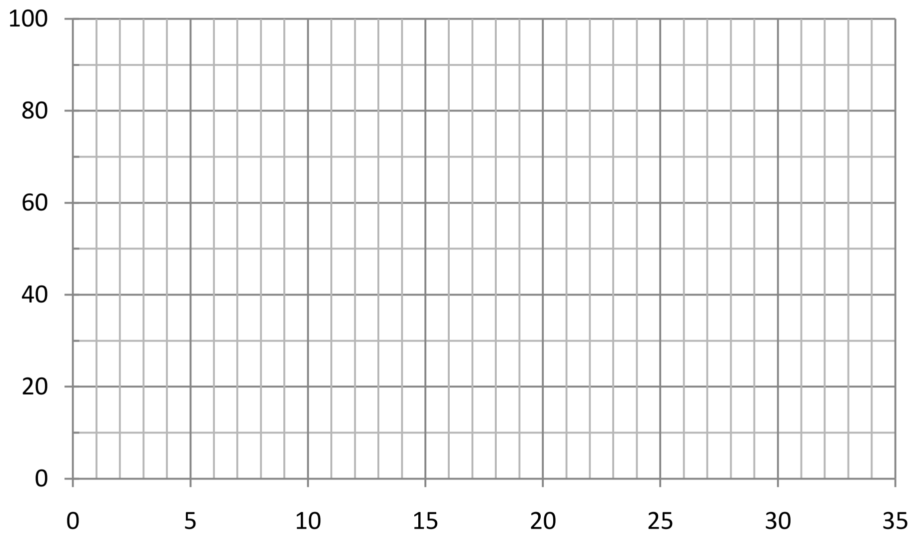
a. 100 cm^3 = _________ dm^3
b. 802 m^3 = _________ cm^3
c. 24 dm^3 = _________ cm^3
d. 0.01 dm^3 = _________ m^3

Score ______ / 8 [__________ %]

Gradient, intercept and rate

12. *Plot a grap*h of the following data and *use it to deduce* the missing volumes, and calculate the gradient and intercept of the line *[6 marks].*

Time (seconds)	Volume of CO_2 released (cm^3)
5	18
10	33
15	48
20	?
25	?
30	93



Score ______ / 8 [__________ %]

Grand total of ____________ / 60 = ____________ %

End of Section 1 Test Answers

Fractions, decimals, ratios and percentages

1. Express the following fractions as (i) percentages, (ii) decimals and (iii) standard form. Give all you answers to *three* significant figures:

   a. $\frac{5}{81}$ (i) ***6.17 %*** (ii) ***0.0617*** (iii) ***6.17×10^{-2}***

   b. $\frac{4}{19}$ (i) ***21.1 %*** (ii) ***0.211*** (iii) ***2.11×10^{-1}***

   c. $\frac{1}{125}$ (i) ***0.800 %*** (ii) ***0.008*** (iii) ***8.00×10^{-3}***

2. In a recent college biology test it was shown that 18 of out every 57 students gained a grade B or above.

   a. Express this information as (i) a percentage, (ii) a decimal and (iii) in standard form. Give all your answers to three significant figures.

      (i) ***31.6 %*** (ii) ***0.316*** (iii) ***3.16×10^{-1}***

   b. Another teacher is setting the same test. How many students would he expect to achieve a grade B or above from a class of 36?

      11

   c. Using the same test a third teacher found that four students gained grade B or above. How many students were in her class?

      13

Score ______ / 14 [__________ %]

Powers and logs

3. Calculate the following:

   a. 4^5 = **1024** b. 2^3 = **8** c. 3^7 = **2187** d. 4^2 = **16**

4. Determine the *logarithms* of the following *numbers*:

   a. 59 **1.8** (1dp)

   b. 7892 **3.9** (2 sig fig)

   c. 4.58×10^{-6} **- 5.34** (3 sig fig)

   d. 4^2 **1.204** (4 sig fig)

   e. 1.111 **0.046** (2 sig fig)

5. Determine the *numbers* of the following *logarithms*. Give your answers to the appropriate precision.

   a. 59 **$1.0\text{x}10^{59}$** (2 sig fig)

   b. -0.7892 **0.1625** (4 sig fig)

   c. 4.58×10^{-6} **1** (1 sig fig)

   d. $4^{0.3}$ **30** (1 sig fig)

   e. 10.8 **$6.31\text{x}10^{10}$** (standard form)

Score ______ / 14 [__________ %]

Rearranging equations

6. By rearranging the equation $A \text{ x } B \text{ x } C = D \text{ x } E \text{ x } F$, make each of the following the subject of the equation:

    (i) A = $\frac{\boldsymbol{D \text{ x } E \text{ x } F}}{\boldsymbol{B \text{ x } C}}$

    (ii) C = $\frac{\boldsymbol{D \text{ x } E \text{ x } F}}{\boldsymbol{A \text{ x } B}}$

    (iii) D = $\frac{\boldsymbol{A \text{ x } B \text{ x } C}}{\boldsymbol{E \text{ x } F}}$

    (iv) E = $\frac{\boldsymbol{A \text{ x } B \text{ x } C}}{\boldsymbol{D \text{ x } F}}$

7. Rearrange the following equation

$$A = \frac{B \text{ x } C}{D \text{ x } E}$$

    (i) B = $\frac{\boldsymbol{A \text{ x } D \text{ x } E}}{\boldsymbol{C}}$

    (ii) C = $\frac{\boldsymbol{A \text{ x } D \text{ x } E}}{\boldsymbol{B}}$

    (iii) D = $\frac{\boldsymbol{B \text{ x } C}}{\boldsymbol{A \text{ x } E}}$

    (iv) E = $\frac{\boldsymbol{B \text{ x } C}}{\boldsymbol{A \text{ x } D}}$

8. By rearranging the equation $A + B - C = D + E - F$, make each of the following the subject of the equation:

    (i) A = **D + E – F – B + C**

    (ii) B = **D + E – F – A + C**

    (iii) C = **A + B – D – E + F**

    (iv) E = **A + B – C – D + F**

    (v) F = **D + E – A – B + C**

9. Rearrange the following equation

$$A = \frac{B + C}{1000}$$

(i) B = **(1000 A) - C**

(ii) C = **(1000 A) - B**

(iii) $1000 = \frac{\boldsymbol{B+C}}{\boldsymbol{A}}$

Score ______ / 16 [__________ %]

Unit conversions

10. Express the following *masses* as the specified units:

a. 10 g = **0.01 kg**
b. 802 mg = **8.02×10^{-4} kg**
c. 145 kg = **145 000 g**
d. 14 mg = **0.014 g**

11. Express the following *volumes* as the units specified n the questions:

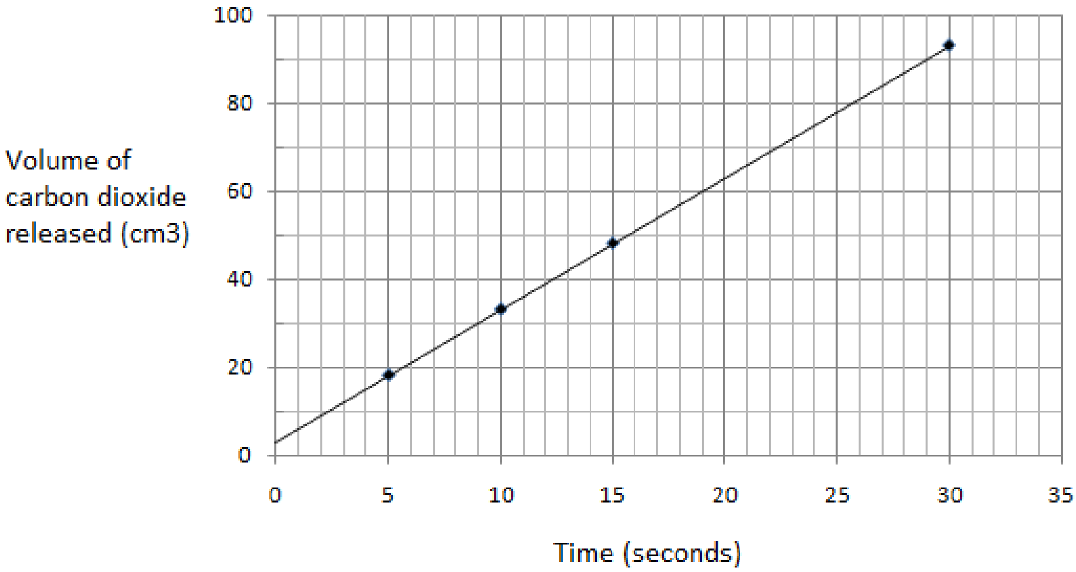
a. 100 cm^3 = **0.1 dm^3**
b. 802 m^3 = **8.02×10^6 cm^3**
c. 24 dm^3 = **24 000 cm^3**
d. 0.01 dm^3 = **1×10^{-5} m^3**

Score ______ / 8 [__________ %]

Gradient, intercept and rate

12. *Plot a grap*h of the following data and *use it to deduce* the missing volumes, and calculate the gradient and intercept of the line *[6 marks].*

Time (seconds)	Volume of CO_2 released (cm^3)
5	12
10	22
15	32
20	**42 [1 mark]**
25	**52 [1mark]**
30	62



[1 mark] correctly labelled x-axis **[1 mark] correctly labelled y=axis**
[1 mark] correctly plotted points **[1 mark] line placed through data**
[1 mark] gradient = 2 **[1 mark] intercept = 2**

Score ______ / 8 [__________ %]

Grand total of ____________ / 60 = ____________ %

Section 2: Calculations in AS Biology Specifications

Very few concepts in biology strike fear into the hearts of students like data handling questions. A close second is magnification because of the conversion of units, and the AS biology specs have both! If the teacher doesn't put it in the right way at the start then your confidence in these relatively straight forward concepts gets dented, and it often doesn't recover even by A2. This section puts this right, and shows you just how to go about the calculation content without the fear...

The art of reading questions

Too many people misread the question and lose marks pointlessly. They *describe* when they should have *explained*; did not *use the data* when asked to, or failed to use figures when describing graphs.

While each board publishes their own glossary of terms, it is possible to combine them into a clear set of instructions you can follow to help you answer the questions appropriately. The terms below represent the ones that are most relevant for the mathematical requirement.

Criteria	Instruction
Analyse and interpret	Identify the **essential features** of the information or data provided. There should be **reasons behind the features** and it's likely that **some data manipulation** would be expected.
Appreciate	Show **awareness of the significance** of the data or underlying principles but without detailed knowledge.
Brief	Short statements of only the **main points.**
Calculate	**Work out** an answer & **show a clear route of derivation** to the answer.
Compare	Discuss the **similarities and differences** between two or more variables. Outline similarities and differences separately.
Contrast	Like compare, but the **emphasis will be on differences**.
Criticise	**Highlight any faults**, shortcomings or limitations of an experiment.
Describe	Simply put; "**Say what you see with figures**". Any descriptions must relate directly to the information provided. It must be concise and straight-forward. Any **trend should be presented in words or translated mathematically**. If numerical data is being described, there must be **specific references to figures**. Figures should normally be manipulated in some way (e.g. percentage changes etc).
Distinguish	**Identify any appropriate differences.**
Evaluate	To judge or **determine the significance** of the information. States what's **good and bad** about the conclusions.
Graphs	Be careful to **take notice of any specific instructions** given in the question. **Plot in pencil** so corrections are possible. **Always make the maximum use of the graph paper** for greatest precision. **Axes should be fully labelled** and **include the units** of variables. Always use rulers or flexi-curves to join points. **Never use sketchy lines**.
Using the data or information	**Numerical answer must be provided** using the provided data as a direct source.

Magnification questions

Magnification and actual size

Cells and their organelles are structures that can only be viewed using light or electron microscopes. These instruments magnify the image many times and make it visible. The size of the image you see, the actual size of the organelle and the magnification are all linked by the equation:

$$magnification = \frac{image\ size}{actual\ size}$$

In other words, magnification is a *ratio* of how big something appears compared to its real size. This equation is deceptively simple but it is fraught with tricks that tend to cause common errors. One of the biggest of these is the unit conversions involved. Cell sizes are almost exclusively reported in microns, μm (1×10^{-6} meters), whereas the actual image size can be measured on the exam paper in mm or cm. To avoid any difficulties whatsoever, follow these rules *exactly*:

1. Measure the image size in **mm**.
2. **Multiply** the measurement **by 1000** to convert it to microns.
3. **Rearrange the equation** above depending on what the question is asking for.

There are two types of questions that use this kind of approach; (i) calculation of magnification from an image, (ii) calculation of actual size from the magnification.

? **Worked example 1**: The image below is of a nucleus of an epithelial cell viewed by an electron microscope. The actual size of the organelle shown is 2.5μm. Use this information to calculate the magnification of the diagram.

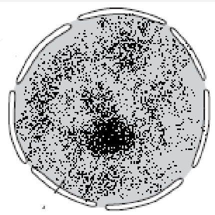


Image diameter = 18 mm

X 1000 = 18 000 μm

$$magnification = \frac{image\ size}{actual\ size} = \frac{18\ 000}{2.5} = 7200$$

? **<u>Worked example 2</u>**: The image below is of a mitochondrion in a skin cell viewed by a transmission electron microscope. The magnification of the diagram is x12 000. Use this information to calculate the actual length of the organelle.

Image length = 16 mm
X 1000 = 16 000 µm

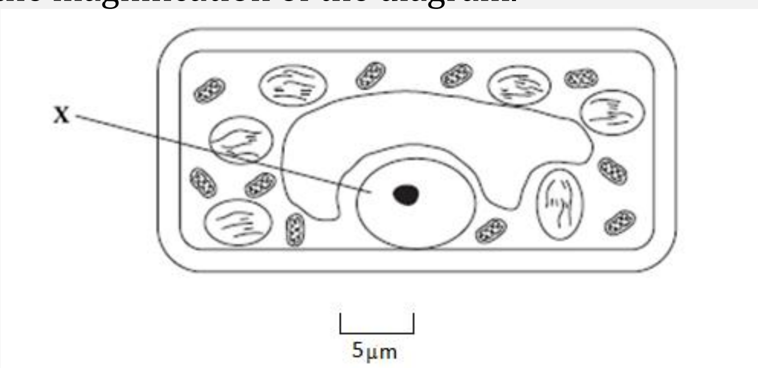
$$actual\ size = \frac{image\ size}{magnification} = \frac{16\ 000}{12\ 000} = 1.33\ \mu m$$

Actual size using a scale bar

Some questions provide the student with a scale bar and demand a calculation of the *actual size* of a cell or organelle. These questions use *ratios* to determine the answer, so follow these instructions:

1. **Measure** the length of the *scale bar* **in mm** and **multiply** the measurement **by 1000** to convert it to microns.
2. **Measure** the length of the image of the *cell* or *organelle* **in mm** and **multiply** the measurement **by 1000** to convert it to microns.
3. Find the **ratio** of **cell length : scale bar length** by dividing the length of the structure by the length of the scale bar.
4. **Multiply the size shown on the scale bar by that many times** to get the actual size of the structure.

? **<u>Worked example 3</u>**: The diagram below shows the image of a palisade cell of a plant. Using the information provided, calculate (i) the maximum length of the palisade cell, and (ii) given that the length of organelle *X* is 8 µm, calculate the magnification of the diagram.



(i) Length of scale bar = 7.5 mm = 7500 μm
Length of image of cell = 52 mm = 52 000 μm
Ratio cell : scale bar = 52000 / 7500 = 6.93
Actual cell length = 6.93 x 5 = **34.7 μm**

(ii) Image diameter = 12 mm
X 1000 = 12 000 μm

$$magnification = \frac{image\ size}{actual\ size} = \frac{12\ 000}{8} = 1500$$

Always do measurements in **mm** never cm.

Heart, breathing and cycle rates

Like many organs and systems, the heart and lungs follow a pattern of cyclical changes that repeat after a certain time interval. Each cycle therefore takes a specific amount of time to complete. The rate (*cycles per unit time*) can be found by dividing the time unit by the time of one cycle.

$$Heart\ rate\ (beats\ per\ minute) = \frac{60}{time\ for\ one\ beat\ (seconds)}$$

Other cycles follow a similar pattern, the only difficulty that you will face in the questions is being conscious of the units involved; whether the rate is *cycles per second*, *minutes* or *hours*.

All these cyclical questions are based around the equation that you will probably be familiar with from GCSE physics:

distance = *speed* x *time*

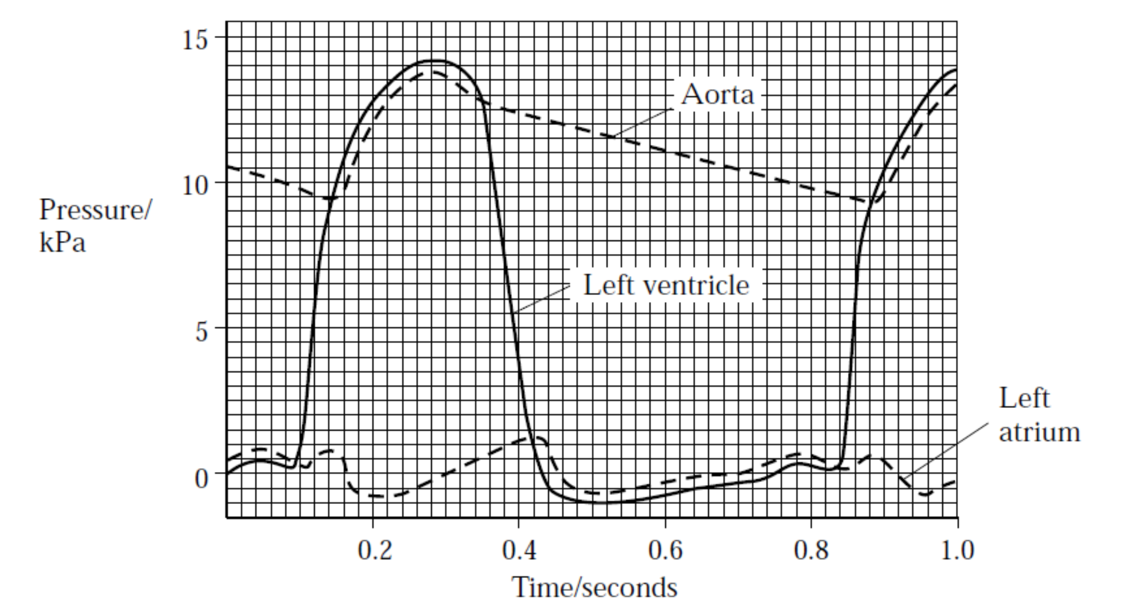
Almost all the questions will be in the form of graphs. The independent variable on the x-axis will usually be time in a specified unit. To determine the length of time it takes for one cycle:

1. Identify a point on two cycles that are at the **same point** on the cycle.
2. For each point **read the value of the x-axis** (time).
3. The length of one cycle = **higher time – lower time**.
4. The cycle **rate (per minute) = 60 ÷ length of one cycle**

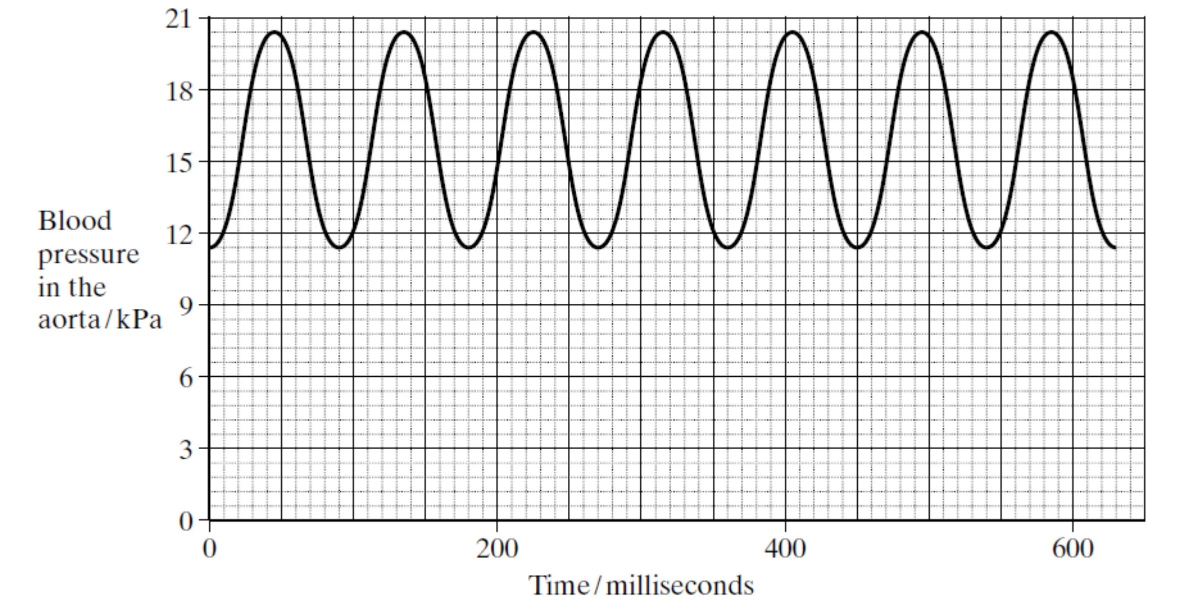
? Worked example 4: The diagram below shows the pressure changes in three chambers of the heart during the cardiac cycle. Use the graph to calculate (i) the time taken for one heart beat, and (ii) the heart rate of the of the individual shown. Give a suitable unit.

(i) Common point on both cycles where the aorta crosses the left ventricle; is 0.9 – 0.14 = **0.76 seconds**

(ii) Heart rate = 60 ÷ 0.76 = **79 beats per minute.**



? Worked example 5: The vole is a small mammal that has a much higher metabolic rate than a human. The diagram over the page shows the pressure changes in the aorta of a vole. Use the graph to calculate the heart rate of the vole. Give a suitable unit in your answer.



The common point on all the cycles is at the base of the cycles;
450 – 360 = **90 milliseconds.**
90 milliseconds = $90\text{x}10^{-3}$ seconds.
Heart rate = 60 ÷ $90\text{x}10^{-3}$ = **667 beats per minute.**

Osmosis

Osmosis is the *net* movement of water across a partially permeable membrane from an area of high water potential (high concentration *of water*) to an area of lower water potential (lower concentration *of water*). It is usually expressed as a pressure in units of *kPa*.

When the water potential of the surrounding solution is *higher* than that inside the cell, water moves *into* the cell by osmosis and the cell will swell up. When the water potential of the surrounding solution is *lower* than that inside the cell, water moves *out of* the cell by osmosis and the cell will shrivel up.

The two common types of question at AS are using the equation $\Psi_{cell} = \Psi_s + \Psi_p$ and also those involving the experimental determination of the concentration at which the water potential of a solution is equal to the water potential of plant tissues such as potato tuber.

$\Psi_{cell} = \Psi_s + \Psi_p$

The water potential of a cell is given by, $\Psi_{cell} = \Psi_s + \Psi_p$ where Ψ_{cell} is the water potential of the cell and Ψ_s and Ψ_p are the solute potential and the pressure potential respectively. The key to these types of question is being able to rearrange the equation correctly.

? **Worked example 6**: The table below shows some values of water potential for three adjacent cells in the leaf of a plant. Use your knowedge of the relationship between the water potential of the cell, Ψ_{cell} and solute potential, Ψ_s and pressure potential, Ψ_p to fill in the blank values of the table.

Cell	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
A		– 1400	+ 600
B	– 400		+ 300
C	–1000	– 800	

Fill in the missing boxes.

Cell	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
A	**– 800** = – 1400 + 600	– 1400	+ 600
B	– 400	**– 700** = – 400 – 300	+ 300
C	–1000	– 800	**– 200** = – 1000 – –800

Experimental determination of water potential

This is an experiment you may even have done at GCSE, you know the one! Chop up pieces of potato or carrot and leave them for a few hours in different solutions of a range of solute (sucrose or sodium chloride) concentrations. If the water potential of the solution is higher than that of the potato, *water moves into the cells* by osmosis and the potato increases its length or mass. Conversely if the water potential of the solution is lower than the potato, *water moves out of the cells* by osmosis and the length or mass decreases.

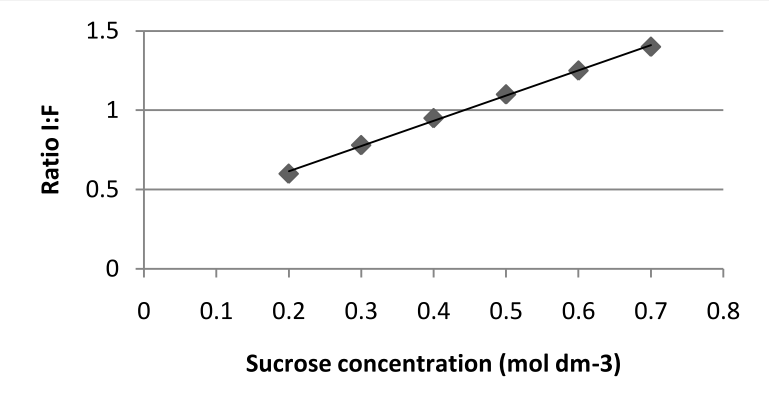
The objective of this experiment is to determine the concentration of solute which has the same water potential as the potatoes; at this point the water potentials will be equal and there will be no net movement of water. In other words the ***change in mass*** will be **zero**. If a ***ratio*** of final mass (or length) to initial mass (or length) is used then the ratio when the water potentials are equal will be **1**. It is the data handling aspect of this experiment is what makes it of particular interest to examiners.

1. **Plot a graph** of **solute concentration** (independent variable, x-axis) against the **ratio** of final to initial mass or weight (dependent variable, y-axis).
2. A **ratio** is used to **standardise** the data against small differences in initial mass.
3. Draw **a line of best fit** through the data.
4. **Identify the concentration of solute** which **gives a ratio of 1** (no net movement of water).

? Worked example 7: A student designed an experiment to investigate the effect of sucrose concentration on the masses of 5 mm cubes of potato tuber cut from a single potato. He rinsed and dried each cube and placed it in a certain sucrose concentration for 4 hours. He then dabbed the cubes on tissue paper to remove excess solution and re-weighed them.

Sucrose (mol dm^{-3})	0.2	0.3	0.4	0.5	0.6	0.7
Ratio of initial to final length	0.6	0.78	0.95	1.1	1.25	1.4

Plot a graph of the data and use it to determine the concentration of sucrose which has the same water potential as the pieces of potato.



The water potential of the potato is the same as the sucrose concentration when the ratio is 1, = **0.45 mol dm^{-3}**.

Look carefully; if you use a **ratio** (read off at **1**) or **difference** in mass (read off at **0**)

Nucleotide bases in DNA/RNA

Number of bases on DNA and amino acids in proteins

Nucleic acids such as deoxyribonucleic acid, DNA and ribonucleic acid, RNA carry the genetic code that determines the primary structure of proteins. The code is a triplet code as **three bases** on DNA or RNA code for **one amino acid** in the peptide chain. It follows that:

$$number\ of\ bases\ on\ DNA = number\ of\ amino\ acids \times 3$$

$$number\ of\ amino\ acids = \frac{number\ of\ bases\ on\ DNA}{3}$$

? <u>Worked example 8</u>: As part of the *human genome project* scientists determined the sequence of bases on all human genes. One gene on chromosome 12 was composed of 927 bases on its DNA. What is the maximum number of amino acids in the protein that is coded for by this gene?

$$Number\ of\ amino\ acids = \frac{927}{3} = \mathbf{309\ amino\ acids}$$

? <u>Worked example 9:</u> Some proteins have quaternary structure and are made up of two or more tertiary structures combined together. One such protein is made up of two subunits. Subunit A has 8000 amino acids and subunit B has 3300 amino acids. Deduce the number of bases on DNA required to code for the finished protein.

$$Total\ number\ of\ amino\ acids\ in\ finished\ protein = 8000 + 3300 = 11300$$

$$Number\ of\ bases\ on\ DNA = 11300 \times 3 = \underline{\mathbf{33900}}\ \text{or } 33903^*$$

*You will often see in mark schemes that an alternative answer that is three more bases is allowed. This is because of the **stop codon** that some teachers cover in AS.

Ratios of A:T, C:G

There are four types of base on DNA, adenine, A, thymine, T, cytosine, C and Guanine, G. Through specific base pairing A always binds with T and C always binds with G. In the DNA double helix, it follows that the amount of A always matches T and the amount of C is always the same as G, but the AT amount is usually different to the CG.

The questions asked in exams usually revolve around you being given the % of a given base in a piece of double-stranded DNA and then having to deduce the % amounts of the other three bases. The process is the same for any base, but let's use *A* as an example:

1. If A = A%, then T = A%
2. X = 100 – (A% + T%)
3. C% = X ÷ 2, G% = X ÷ 2

This may seem a bit daft but it's a very simple calculation in practice.

? <u>Worked example 10</u>: Thirty two percent (32%) of the bases extracted from piece of DNA of a zebra was found to be adenine. Deduce the percentages of the other three bases in the DNA.

% thymine = % adenine = **32%**
X = 100 – (32% + 32%) = 100 – 64 = 36%
% cytosine = 36 ÷ 2 = **18%**
% guanine = 36 ÷ 2 = **18%**

? <u>Worked example 11</u>: The gene for mouse insulin has 210 bases on the coding strand of DNA. Fifty eight (58) of these bases are thymine. Deduce the numbers of the other three bases on the **double-stranded** piece of DNA.

Total bases on the coding and non-coding strands = 210 x 2 = 420
n thymine on DNA = 58 x 2 = 116 bases
n adenine = n thymine = **116**
X = 420 – (116 + 116) = 420 – 236 = 184
% cytosine = 184 ÷ 2 = **92**
% guanine = 184 ÷ 2 = **92**

Index of diversity

Diversity index is a **measure of species diversity** in a given area or habitat. It is a **better indicator** of diversity than a simple number of different species present as it not only considers the **range of species** present but also takes into account the **abundance** of each species. The index of diversity, d is given by:

$$d = \frac{N\ (N-1)}{\sum n\ (n-1)}$$

where N = total number of organisms of all species
and n = total number of organisms of each species

? Worked example 12: Calculate the diversity index, *d* for the two habitats X and Y from the data below.

Species found	Numbers found in habitat X	Numbers found in habitat Y
A	10	3
B	10	5
C	10	2
D	10	36
E	10	4
Number of species	**5**	**5**
No. of individuals	**50**	**50**

First calculate n (n-1) for each species in the habitat.
Next calculate the sum of, ∑ n(n-1) by adding them all up.

Species	Numbers (n) found in X	n(n-1)	Numbers (n) found in Y	n(n-1)
A	10	10 x 9 = **90**	3	3 x 2 = **6**
B	10	10 x 9 = **90**	5	5 x 4 = **20**
C	10	10 x 9 = **90**	2	2 x 1 = **2**
D	10	10 x 9 = **90**	36	36 x 35 = **1260**
E	10	10 x 9 = **90**	4	4 x 3 = **12**
	∑ n(n-1)	**450**	∑ n(n-1)	**1300**

$$Habitat\ X, d = \frac{N\ (N-1)}{\sum n\ (n-1)} = \frac{50 \text{ x } 49}{450} = \mathbf{5.44}$$

$$Habitat\ Y, d = \frac{N\ (N-1)}{\sum n\ (n-1)} = \frac{50 \text{ x } 49}{1300} = \mathbf{1.88}$$

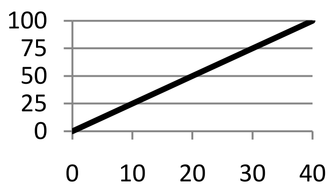
Data handling and interpretation

The data handling component seems to concern many students as it appears at first sight that *they can ask anything*. The fundamentals of data handling are straight forward enough, it just takes a bit of practice and confidence to apply them. In this section you will find out how to standardise descriptions and give some relatively standard answers to some seemingly non-standard questions.

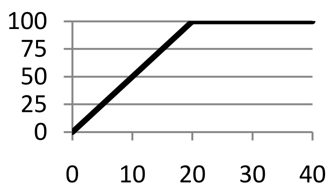
Describing lines

Describing graphs and the changes they show is a fundamental expectation in the A-level exams that's usually worth between 2 and 4 marks. Since the introduction of a much more involved *How Science Works* component, some boards (Edexcel and AQA for example) seem to put a greater emphasis on the data handling skill and so there can be more marks available for description. And they are easy marks in that you are *saying what you see with figures*, and as such do not require any prior biological knowledge.

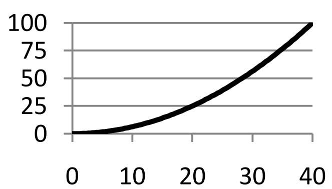
Included below are a variety of different shaped graphs that are of a type often used in exams. Each one is accompanied by a simple and standardised way of describing it that would get the marks. Remember that if this was a real exam you would substitute in time or mass or whatever the axis was instead of saying *x* and *y*.



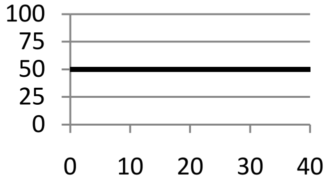
As x increases from 0 to 40, y increases *proportionally* up to 100.



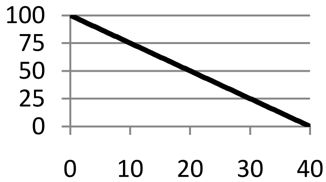
As x increases from 0 to 20, y increases proportionally. When x > 20 y remains constant at 100.



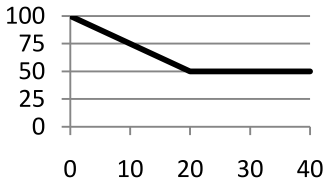
As x increases from 0 to 40, y increases with a gradient that gets steeper as x increases.



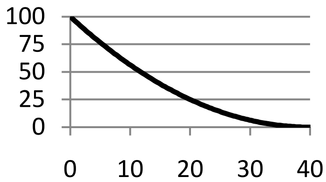
As x increases from 0 to 40, y remains constant at 50.



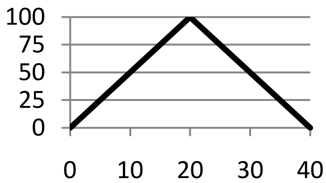
As x increases from 0 to 40, y decreases proportionally.



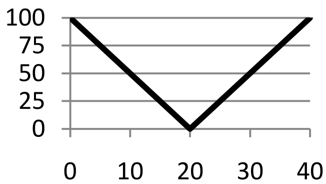
As x increases from 0 to 20, y decreases proportionally. When x > 20 y remains constant at 50.



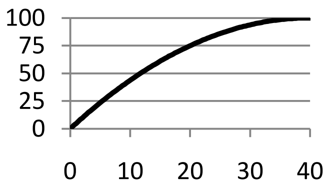
As x increases from 0 to 40, y decreases with a gradient that gets less steep as x increases.



As x increases from 0 to 20, y increases proportionally up to a maximum of 100. As x continues to increase above 20 y decreases proportionally to 0.



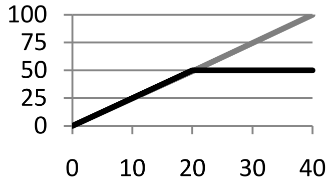
As x increases from 0 to 20, y decreases proportionally to a minimum of 0. As x continues to increase above 20 y increases proportionally to 100.



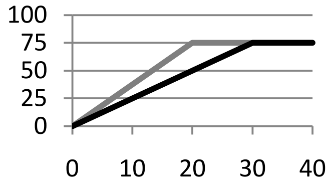
As x increases up to 40, y increases with a decreasing gradient up to a maximum of 100.

Comparing lines

When comparing two graphs the key is to visualise any ***similarities and* differences**. Like with *description*, using figures here will be of fundamental importance to scoring the maximum marks.



For both curves A and B as x increases up to 20, y increases proportionally, with both A and B having the same gradient. When x > 40, A continues to increase proportionally whereas B remains constant at 50.



For both curves, as x increases y increases proportionally and then it remains constant at the same value at 75. The gradient of B is lower than the gradient of A.

There are so many different combinations that could be asked but the principle is the same, *say what is similar and what is different* about the two lines.

Data manipulation

When using experimental data it is often necessary to manipulate the data in some way to help visualise the trends and make interpretation clearer. In many data handling questions there are certain themes and calculations which recur in different contexts. Included below is a list of standard contexts and guidelines on how to deal with them effectively.

Standardisation of y-axis data

Percentages

Percentages express fractions *out of 100*. It is a way of making data more instantly comparable. For example the data were to show a decrease in the serum cholesterol levels at varying times on a certain drug; the data may be expressed at a % of the original cholesterol level. It allows a comparison as these initial values were not identical to start with.

Ratio
Ratios are like percentages in that they allow a comparison of data in cases where the initial amounts of start materials may have varied. In osmosis studies it is common to study the change in mass, or length of a piece of potato or beetroot when exposed to different concentrations of sucrose solution. A ratio of final length to initial length in an osmosis study gives a clear indication of whether water had a net movement into or out of cells. The ratio is used, rather than the absolute changes in mass or length because the initial masses or lengths varied slightly.

Difference in mass or length
This is a manipulation similar to taking a ratio. It is not as useful as using a ratio as the amount it changes by may also depend on the initial value.

Expressing data as "something per something"
The data on the y axis can be expressed as x *per* y or *out of* y (e.g. number of cases *per* 100 000 people, or amount of food *per* gram of mouse). They will ask you why the data is expressed *per* something. The standard *2 mark* answer: [1] It **allows a comparison**, [1] **because ______ differs** or changes.

For example; the *number of deaths per 100 000 people* is proportional to the amount of saturated fat in the diet of different countries. The data is expressed *per 100 000 people* as **it allows a comparison** because **the number of people in each country is different**.

For example; the *blood concentration of a drug per kg of body mass* is proportional to the BMI of the patient in a variety of ethnic groups studied. The data is expressed *per kg of body mass* as **it allows a comparison** because **the body masses of the ethnic groups varied**.

% increase and decrease
If by changing the independent variable there is an increase in the dependent then it is common to ask you to calculate this change as a % increase rather than an absolute change. This can be calculated using the equation.

$$\%\ increase\ = \frac{bigger - smaller}{smaller} \text{ x } 100$$

$$\%\ decrease\ = \frac{bigger - smaller}{bigger} \text{ x } 100$$

? <u>Worked example 13</u>: The data below shows the effect of a male fertility drug on the numbers of sperm produced by men over a 6 month period of treatment. Use the data to calculate (i) the percentage increase in sperm counts between months 1 and 3 and (ii) the % decrease in sperm count between months 5 and 6.

Treatment month	Sperm count (millions / cm^3)
0	84
1	82
2	86
3	93
4	120
5	176
6	89

$$(i)\ \%\ increase\ months\ 1\ to\ 3\ = \frac{bigger - smaller}{smaller} \text{ x } 100$$

$$\%\ increase\ = \frac{93 - 82}{82} \text{ x } 100 = \mathbf{13.4\%}$$

$$(ii)\ \%\ decrease\ months\ 5\ to\ 6\ = \frac{bigger - smaller}{bigger} \text{ x } 100$$

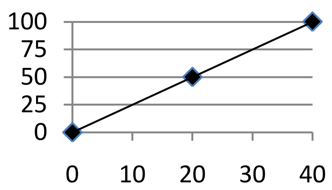
$$\%\ increase\ = \frac{176 - 89}{176} \text{ x } 100 = \mathbf{49.4\%}$$

A simple way of remembering which way round it is, is to imagine your **start point**; So if it is a *decrease* you are **starting big** and going little (so you **divide by big**) and if it is an increase you are **starting little** and going big (so you **divide by little**).

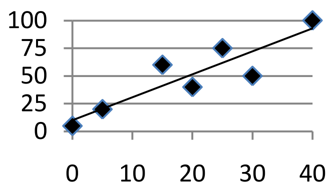
Causation and correlation

All the boards are keen on testing your appreciation of the difference between causation and correlation. ***Causation*** is a change in one variable that results from (or is caused by) a change in another variable (a change in one causes the other to change as well). A ***correlation*** shows a relationship between two variables. Evidence of correlation does not automatically imply causation.

The simplest way to distinguish between causation and correlation is to use a scatter diagram:



Causation; if a change in the independent variable **causes** a change in the dependent variable then the scatter diagram between them will **go through the origin** (have an intercept of *zero*). In addition, the points will lie **exactly on a straight line** because, in the absence of x there can be no effect on y and no other factor has an effect.



Correlation; if a change in the independent variable **correlates** with a change in the dependent variable then the scatter diagram between them will **not necessarily go through the origin** (have an intercept $\neq$ zero). The points will lie **scattered around a straight line** because other factors that are not being controlled are also having an effect.

If asked if a scatter diagram shows that x *causes* y, then if there is any scatter around the line the standard answer would be that **no, x and y show a correlation** but **other factors (such as** __*insert biology knowledge here*___**) have an effect**.

End of Section 2 Test

$$magnification = \frac{image\ size}{actual\ size}$$

Magnification questions

	Actual size	Image size	Magnification
1.	0.75 μm	**? mm**	25 000
2.	1.75 μm	**? mm**	100 000
3.	0.50 μm	**? mm**	400
4.	2.00 μm	**? cm**	50 000
5.	0.75 μm	5 cm	**?**
6.	1.75 μm	75 mm	**?**
7.	0.50 μm	45 mm	**?**
8.	2.00 μm	6 cm	**?**
9.	**?**	5 cm	25 000
10.	**?**	75 mm	100 000
11.	**?**	45 mm	400
12.	**?**	6 cm	50 000

Scale bar questions

	Scale bar	Image size	Actual size	Magnification
1.	10 mm = 1 μm	120 mm	**?**	**?**
2.	17 mm = 0.5 μm	85 mm	**?**	**?**
3.	1.5 cm = 0.5 μm	9.4 cm	**?**	**?**
4.	25 mm = 2 μm	10.6 cm	**?**	**?**
5.	10 mm = 1 μm	5.2 cm	**?**	**?**
6.	17 mm = 0.5 μm	95 mm	**?**	**?**
7.	1.5 cm = 0.5 μm	55 mm	**?**	**?**
8.	25 mm = 2 μm	4.6 cm	**?**	**?**
9.	10 mm = 1 μm	3.5 cm	**?**	**?**
10.	17 mm = 0.5 μm	88 mm	**?**	**?**
11.	1.5 cm = 0.5 μm	45 mm	**?**	**?**
12.	25 mm = 2 μm	6 cm	**?**	**?**

Answers over the page →

$$magnification = \frac{image\ size}{actual\ size}$$

Magnification questions

	Actual size	Image size	Magnification
1.	0.75 μm	**18.75 mm**	25 000
2.	1.75 μm	**175 mm**	100 000
3.	0.50 μm	**0.2 mm**	400
4.	2.00 μm	**10 cm**	50 000
5.	0.75 μm	5 cm	**66 667**
6.	1.75 μm	75 mm	**42 857**
7.	0.50 μm	45 mm	**90 000**
8.	2.00 μm	6 cm	**30 000**
9.	**2 μm**	5 cm	25 000
10.	**0.75 μm**	75 mm	100 000
11.	**112.5 μm**	45 mm	400
12.	**1.2 μm**	6 cm	50 000

Scale bar questions

	Scale bar	Image size	Actual size	Magnification
1.	10 mm = 1 μm	120 mm	**12 μm**	**10 000**
2.	17 mm = 0.5 μm	85 mm	**2.5 μm**	**34 000**
3.	1.5 cm = 0.5 μm	9.4 cm	**3.13 μm**	**30 032**
4.	25 mm = 2 μm	10.6 cm	**8.48 μm**	**12 500**
5.	10 mm = 1 μm	5.2 cm	**5.2 μm**	**10 000**
6.	17 mm = 0.5 μm	95 mm	**2.79 μm**	**34 050**
7.	1.5 cm = 0.5 μm	55 mm	**1.83 μm**	**30 055**
8.	25 mm = 2 μm	4.6 cm	**3.68 μm**	**12 500**
9.	10 mm = 1 μm	3.5 cm	**3.5 μm**	**10 000**
10.	17 mm = 0.5 μm	88 mm	**2.59 μm**	**33 977**
11.	1.5 cm = 0.5 μm	45 mm	**1.5 μm**	**30 000**
12.	25 mm = 2 μm	6 cm	**4.8 μm**	**12 500**

More questions over the page →

$$number\ of\ amino\ acids = \frac{number\ of\ bases\ on\ DNA}{3}$$

Amino acids and DNA bases questions

	Amino acids	DNA bases
1.	120 000	**?**
2.	55	**?**
3.	5874	**?**
4.	1200	**?**
5.	597	**?**
6.	18 700	**?**
7.	**?**	3396
8.	**?**	18 270
9.	**?**	946 362
10.	**?**	18333
11.	**?**	54789
12.	**?**	4296

% of bases on DNA

	Adenine	Cytosine	Thymine	Guanine
1.	**19**	**?**	**?**	**?**
2.	**5**	**?**	**?**	**?**
3.	**24**	**?**	**?**	**?**
4.	**?**	**2**	**?**	**?**
5.	**?**	**12**	**?**	**?**
6.	**?**	**8**	**?**	**?**
7.	**?**	**?**	**17**	**?**
8.	**?**	**?**	**44**	**?**
9.	**?**	**?**	**8**	**?**
10.	**?**	**?**	**?**	**36**
11.	**?**	**?**	**?**	**27**
12.	**?**	**?**	**?**	**14**

Answers over the page →

$$number\ of\ amino\ acids = \frac{number\ of\ bases\ on\ DNA}{3}$$

Amino acids and DNA bases questions

	Amino acids	DNA bases
1.	120 000	**360 000**
2.	55	**165**
3.	5874	**17 622**
4.	1200	**3600**
5.	597	**1791**
6.	18 700	**56 100**
7.	**1132**	3396
8.	**6090**	18 270
9.	**315 454**	946 362
10.	**6111**	18333
11.	**18 263**	54789
12.	**1432**	4296

% of bases on DNA

	Adenine	Cytosine	Thymine	Guanine
1.	19	**31**	**19**	**31**
2.	5	**45**	**5**	**45**
3.	24	**26**	**24**	**26**
4.	**48**	2	**48**	**2**
5.	**38**	12	**38**	**12**
6.	**42**	8	**42**	**8**
7.	**17**	**33**	17	**33**
8.	**44**	**6**	44	**6**
9.	**8**	**42**	8	**42**
10.	**14**	**36**	**14**	36
11.	**23**	**27**	**23**	27
12.	**36**	**14**	**36**	14

More questions over the page →

$$\Psi_{cell} = \Psi_s + \Psi_p$$

Osmosis questions

	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
1.	– 200	**?**	+ 500
2.	– 1200	**?**	+ 300
3.	– 800	**?**	+ 200
4.	– 750	**?**	+ 750
5.	– 200	– 400	**?**
6.	– 1200	– 1000	**?**
7.	– 800	– 300	**?**
8.	– 750	– 250	**?**
9.	**?**	– 400	+ 350
10.	**?**	– 1000	+ 500
11.	**?**	– 300	+ 100
12.	**?**	– 250	+ 250

Cycle questions

	Duration	Rate
1.	0.70 seconds	**? per minute**
2.	0.64 seconds	**? per minute**
3.	0.50 milliseconds	**? per second**
4.	0.89 seconds	**? per minute**
5.	2.00 milliseconds	**? per minute**
6.	1.25 minutes	**? per hour**
7.	**?**	14 per minute
8.	**?**	89 per minute
9.	**?**	500 per second
10.	**?**	225 per second
11.	**?**	97 per minute
12.	**?**	6 per hour

Answers over the page →

$$\Psi_{cell} = \Psi_s + \Psi_p$$

Osmosis questions

	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
1.	– 200	**– 700**	+ 500
2.	– 1200	**– 1500**	+ 300
3.	– 800	**– 1000**	+ 200
4.	– 750	**– 1500**	+ 750
5.	– 200	– 400	**+ 200**
6.	– 1200	– 1000	**– 200**
7.	– 800	– 300	**– 500**
8.	– 750	– 250	**– 500**
9.	**– 50**	– 400	+ 350
10.	**– 500**	– 1000	+ 500
11.	**– 200**	– 300	+ 100
12.	**0**	– 250	+ 250

Cycle questions

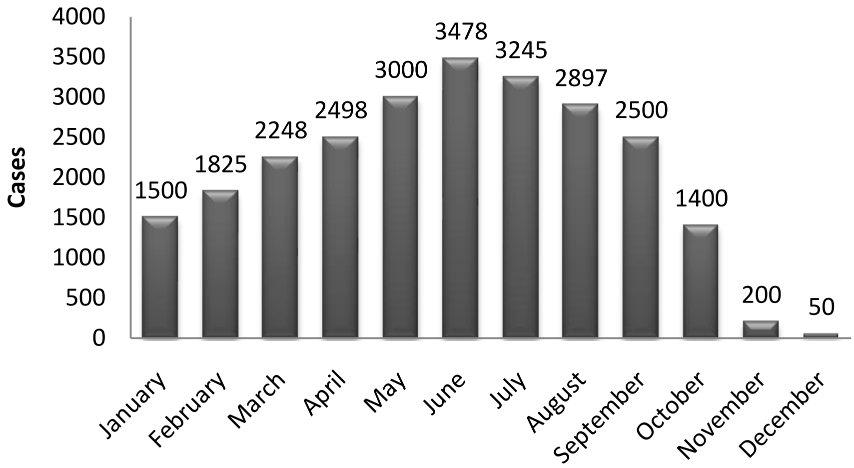
	Duration	Rate
1.	0.70 seconds	**85.7 per minute**
2.	0.64 seconds	**93.8 per minute**
3.	0.50 milliseconds	**2000 per second**
4.	0.89 seconds	**67.4 per minute**
5.	2.00 milliseconds	**30 000 per minute**
6.	1.25 minutes	**48 per hour**
7.	**4.29 seconds**	14.0 per minute
8.	**0.67 seconds**	89 per minute
9.	**2 milliseconds**	500 per second
10.	**4.44 milliseconds**	225 per second
11.	**0.62 seconds**	97 per minute
12.	**10 minutes**	6 per hour

More questions over the page →

$$\% \; increase = \frac{bigger - smaller}{smaller} \times 100$$

$$\% \; decrease = \frac{bigger - smaller}{bigger} \times 100$$

Differences, % increases and % decreases



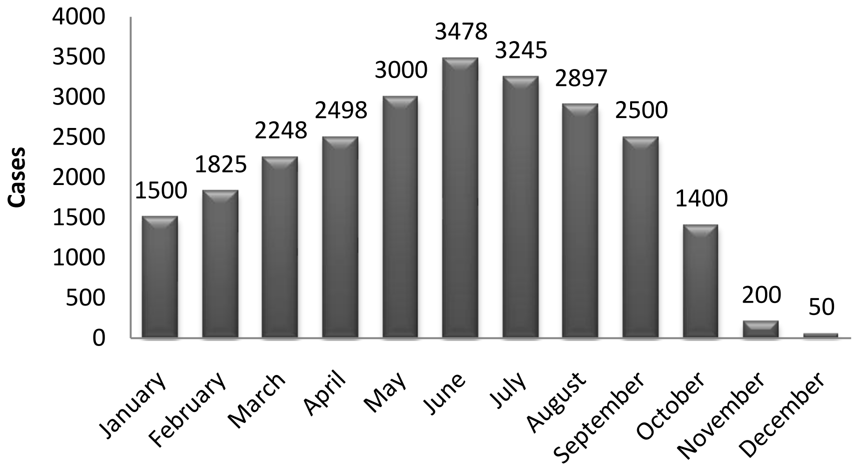
		Difference	% increase
1.	January to February	?	?
2.	January to March	?	?
3.	January to April	?	?
4.	January to May	?	?
5.	January to June	?	?
6.	February to March	?	?
7.	March to April	?	?
8.	April to May	?	?
9.	May to June	?	?
		Difference	**% decrease**
10.	June to July	?	?
11.	June to August	?	?
12.	June to September	?	?
13.	June to October	?	?
14.	June to November	?	?
15.	June to December	?	?
16.	July to August	?	?
17.	August to September	?	?
18.	September to October	?	?

Answers over the page →

$$\%\ increase = \frac{bigger - smaller}{smaller} \text{ x } 100$$

$$\%\ decrease = \frac{bigger - smaller}{bigger} \text{ x } 100$$

Differences, % increases and % decreases



		Difference	% increase
1.	January to February	**325**	**21.7**
2.	January to March	**748**	**49.9**
3.	January to April	**998**	**66.5**
4.	January to May	**1500**	**100**
5.	January to June	**1978**	**132**
6.	February to March	**423**	**23.2**
7.	March to April	**250**	**11.1**
8.	April to May	**502**	**20.1**
9.	May to June	**478**	**15.9**
		Difference	**% decrease**
10.	June to July	**233**	**6.70**
11.	June to August	**581**	**16.7**
12.	June to September	**978**	**28.1**
13.	June to October	**2078**	**59.7**
14.	June to November	**3278**	**94.2**
15.	June to December	**3428**	**98.6**
16.	July to August	**348**	**10.7**
17.	August to September	**397**	**13.7**
18.	September to October	**1100**	**44.0**

More questions over the page →

Pulmonary ventilation = breathing rate x tidal volume

Pulmonary ventilation

	Pulmonary ventilation dm^3 per minute	Breathing rate breaths per minute	Tidal volume dm^3
1.	**?**	15	0.50
2.	**?**	18	0.45
3.	**?**	22	0.61
4.	**?**	14	0.56
5.	25	**?**	0.50
6.	27	**?**	0.45
7.	38	**?**	0.61
8.	14	**?**	0.56
9.	22	30	**?**
10.	18	25	**?**
11.	38	48	**?**
12.	15	21	**?**

Cardiac output = heart rate x stroke volume

Cardiac output

	Cardiac output cm^3 per minute	Heart rate beats per minute	Stroke volume cm^3 per beat
1.	**?**	78	108
2.	**?**	92	112
3.	**?**	105	114
4.	**?**	120	105
5.	5180	**?**	108
6.	18 200	**?**	112
7.	22 500	**?**	114
8.	7800	**?**	105
9.	5180	78	**?**
10.	18 200	92	**?**
11.	22 500	105	**?**
12.	7800	120	**?**

Answers over the page →

Pulmonary ventilation = breathing rate x *tidal volume*

Pulmonary ventilation

	Pulmonary ventilation dm^3 per minute	**Breathing rate** breaths per minute	**Tidal volume** dm^3
1.	**7.50**	15	0.50
2.	**8.10**	18	0.45
3.	**13.42**	22	0.61
4.	**7.84**	14	0.56
5.	25	**50**	0.50
6.	27	**60**	0.45
7.	38	**62**	0.61
8.	14	**25**	0.56
9.	22	30	**0.73**
10.	18	25	**0.72**
11.	38	48	**0.79**
12.	15	21	**0.71**

Cardiac output = heart rate x *stroke volume*

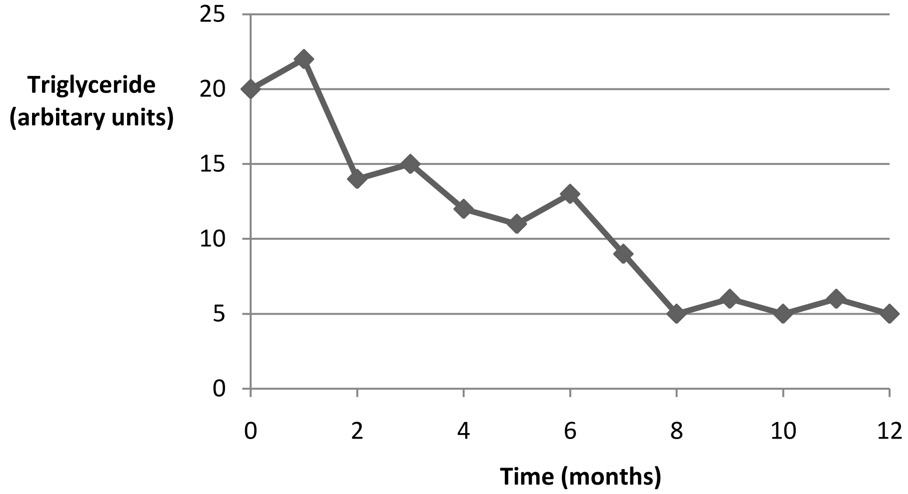
Cardiac output

	Cardiac output dm^3 per minute	**Heart rate** beats per minute	**Stroke volume** cm^3 per beat
1.	**8.42**	78	108
2.	**10.3**	92	112
3.	**11.97**	105	114
4.	**12.6**	120	105
5.	5.18	**48**	108
6.	18.2	**162.5**	112
7.	22.5	**197.4**	114
8.	7.80	**74.2**	105
9.	5.18	78	**66.4**
10.	18.2	92	**197.8**
11.	22.5	105	**214.3**
12.	7.80	120	**65.0**

Section 3: Examination-style Questions

Ok so now you know how to go about the questions it's time to do some real exam-style examples. The questions included here are a mix of questions that follow the styles asked by AQA, OCR, Edexcel and WJEC in the AS modules. As each board covers the same topics in a different order, you need to check which types of question are relevant for the paper you're sitting. The mark schemes include worked answers. I recommend you study them ***after*** you sit the questions to work out how best to improve.

1. The graph shows the blood triglyceride concentration (in arbitrary units) of an overweight man following a diet low in saturated fat. He started the diet at 0 months and over the period of 12 months after starting the diet he lost weight steadily at the rate of 0.5 kg a week.

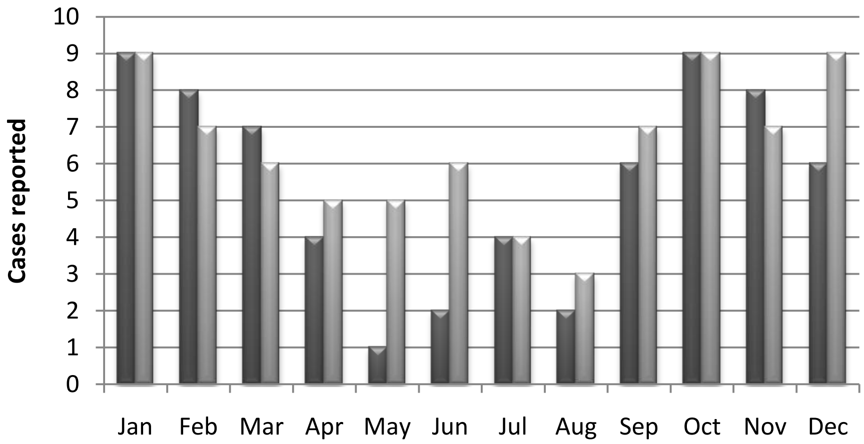


(a) Describe how the concentration of triglyceride in his blood changed over the 12 month period. [2]

(b) Calculate the percentage decrease in his blood triglyceride concentration over the 12 month period. [2]

(c) Evaluate the effectiveness of the man's weight loss on his blood triglyceride concentration. [2]

2. The diagram below shows how the number of cases of flu-like symptoms reported in two villages in Scotland varied over a 12 months period in 2002. Village 1 is shown with darker bars and village 2 with lighter bars).

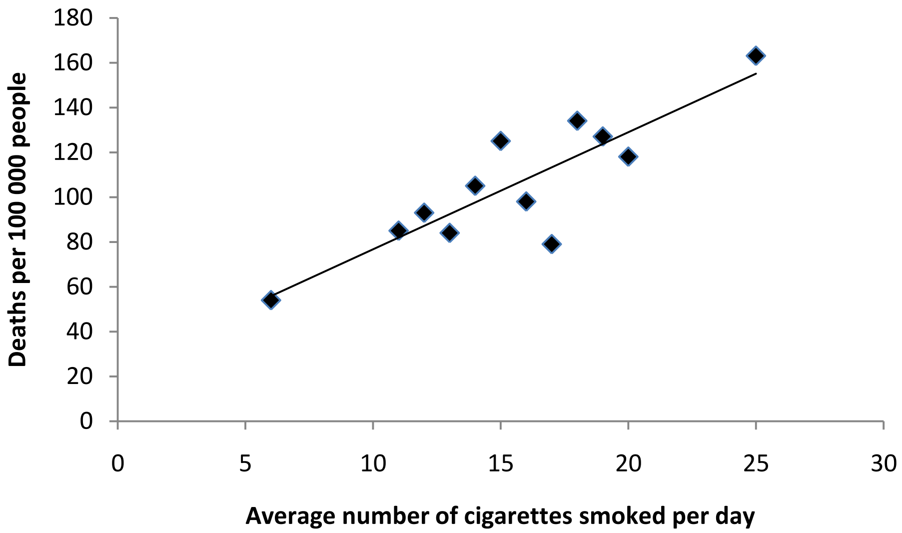


(a) What was the difference in the total number of cases reported in village 1 and 2 over the 12 month period? [3]

(b) Calculate percentage decreases in cases reported in village 2 between January 2002 and August 2002. [2]

(c) Compare the number of cases reported in the two villages over the 12 month period. [3]

3. The graph shows the relationship between the amount of cigarettes smoked and the deaths from lung cancer in different countries.



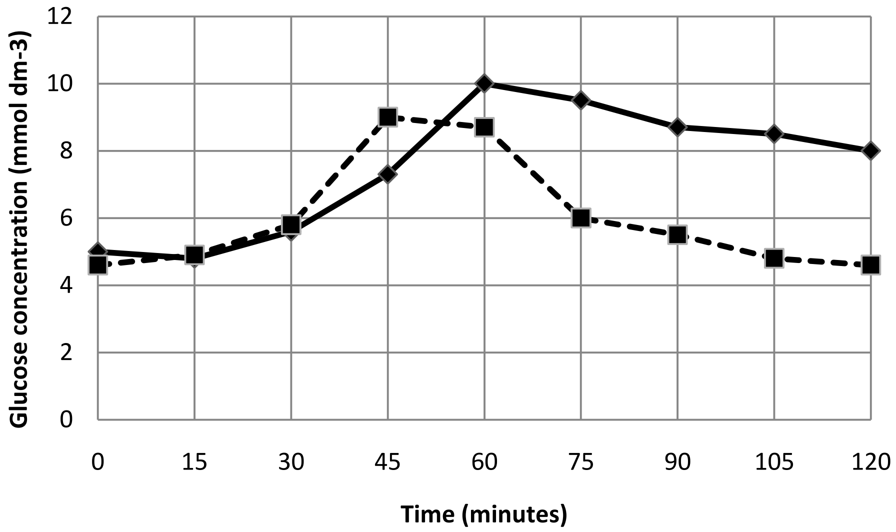
(a) The number of deaths was expressed per 100 000 population. Suggest why? [2]

(b) Does the evidence shown in the graph show that smoking causes lung cancer? Explain your answer. [2]

(c) Another country, Poland wanted to have their data included on the trial. Their estimated deaths per 100 000 was 170. Deduce the average number of cigarettes smoked per day in Poland. [1]

4. Diabetes is a disease which affects the ability of a sufferer to metabolise and use digested glucose. A diabetic man (solid line) and a non-diabetic man (dashed line) were each given a piece of white bread and butter to eat. Their blood glucose concentration was measured over the next two

hours at 15 minute intervals. The results are shown on the graph.



(a) Describe how the diabetic man's blood glucose concentration changed over the 2 hours period. [2]

(b) (i) Calculate the percentage increase in blood glucose concentration for the diabetic man over the first hour. [1]

(ii) Calculate the percentage decrease in blood glucose concentration for the diabetic man over the second hour. [1]

(c) Compare the data shown by the non-diabetic man with that of the diabetic man. [3]

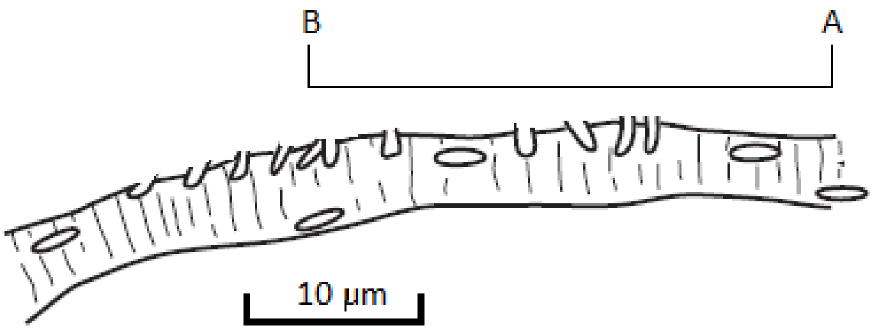
5. Some students performed an investigation to find the concentration of sucrose which had the same water potential as cylinders of potato. They cut pieces of potato with a cork borer and measured their initial length. They then placed them in sealed tubes containing 5 cm^3 of sucrose solutions for 2 hours at 25^0C. After this time they dried the pieces by dabbing them on kitchen roll and measured their final lengths. Their results are shown below.

Concentration of sucrose / mol dm^{-3}	Ratio of final length : initial length
0.0	1.5
0.2	1.5
0.4	1.3
0.6	0.9
0.8	0.4

(a) The students wanted to use the results to find the concentration of sucrose that had the same water potential as the potato cylinders. Describe how they could have done this. [3]

(b) Plot a suitable graph of the results and estimate the concentration of sucrose with the same water potential as the potato. [4]

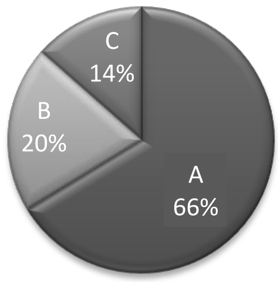
6. The diagram shows part of a blood vessel of a mammal.



(a) Use the information in the diagram to calculate the magnification of the diagram. [2]

(b) The rate of blood flow through the vessel is 0.15 mm sec^{-1}. Calculate how long it would take a blood cell to travel from point A to point B. Show your working. [2]

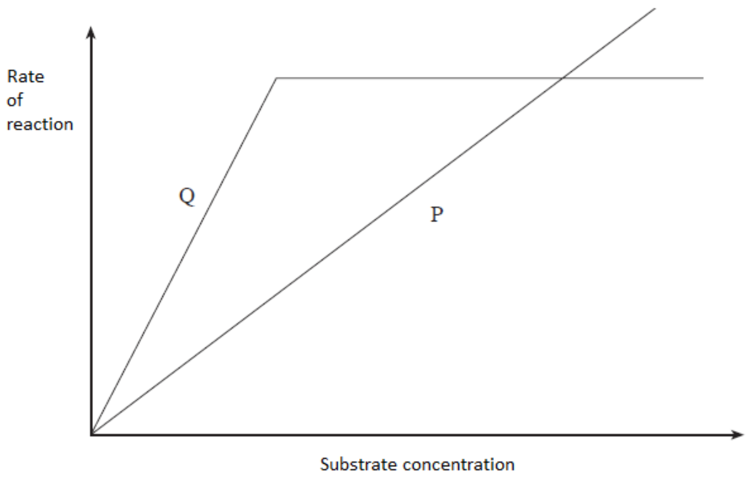
7. The pie chart shows the proportion of people infected with three different strains bird flu in 2009.



(a) The total number of cases of bird flu reported in this group of patients was 895. Calculate the actual number of people infected with strain C. Show your working. [2]

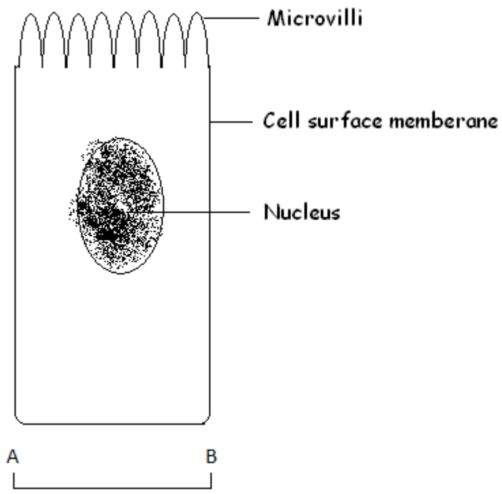
(b) A second study showed that 87 people were infected with strain B. Deduce the number of people in that study. Show your working. [2]

8. The rate of an enzyme-controlled reaction is affected by the concentration of the substrate. The graph below shows the effect of substrate concentration on the rate of two different reactions catalysed by different enzymes P and Q.



(a) Compare the effects of an increase in substrate concentration on the rates of the two enzyme controlled reactions. [4]

9. The epithelial cell below is shown at a magnification of x12 000.



(a) Calculate the actual width of the cell between points A and B. Give you answer in µm and show your working. [2]

(b) How many of these cells would be required to cover 1 mm if they were all laid side by side. Give your answer to the nearest whole number. [2]

10. A scientist investigated the effect of different concentrations of potassium chloride on discs cut from a single pear. He weighed each disc in turn and then placed it into a solution of known concentration for 24 hours. After this time he then weighed the disc again. The results are shown on the table below.

KCl / mol dm^{-3}	Initial mass / g	Final mass / g	Ratio
0	18.7	21.3	1.14
0.2	19.2	20	1.04
0.3	22.2	22.4	
0.4	16.4	15.8	0.96
0.6	21.9	19.3	0.88

(a) Calculate the ratio of start mass to final mass for the disc placed in 0.30 mol dm^{-3} potassium chloride solution. Give your answer to three significant figures [2]

(b) The scientist reported his results as a ratio. What was the advantage of giving his results as a ratio? [2]

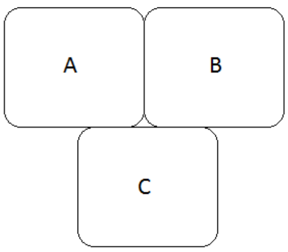
(c) Describe how the scientist could use the data to determine the concentration of potassium chloride solution that has the same water potential as the discs of pear. [2]

11. (a) Give the equation that links the water potential of the cell with the solute and pressure potentials. [1]

(b) Complete the following table.

Cell	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
A		– 1000	+ 500
B	– 200	– 800	
C	– 400		+ 700

(c) Cells A, B and C were placed adjacent to one another. Draw arrows on the diagram to show the movement of water between A and B, A and C, and B and C. [3]



12. A student carried out an experiment using the enzyme catalase and found that its activity was inhibited by the presence of iron (ii) nitrate solution. He obtained the following results.

Iron (ii) nitrate / mol dm^{-3} x 10^{-3}	% Catalase activity
0	100
1	84
2	65
3	46
4	32
5	29

(a) Plot a suitable graph of the data. [4]

(b) Use the graph to deduce the concentration of iron (ii) nitrate that would reduce the activity of the enzyme by 50%. Show your working. [2]

13. The table shows the increase in heart rate of a 20 year old male exposed to air containing 2% carbon dioxide for up to 20 seconds.

Time (seconds)	0	5	10	15	20
heart rate (bpm)	74	76	79	84	83

(a) Describe the effect of the carbon dioxide on the man's breathing rate.[2]

(b) Calculate the maximum percentage increase in breathing rate. Show your working. [2]

14. The length of the organelle shown is 0.5 µm. Calculate the magnification of the diagram. Show your working. [2]

15. The time difference between four peaks on the ECG of a man admitted to hospital with chest pain was found to 1.24, 1.32, 1.28 and 1.29 seconds.

(a) Calculate the average time difference between the peaks. [1]

(b) Use the data to calculate the average heart rate (in beats per minute) of the man. Show your working. [2]

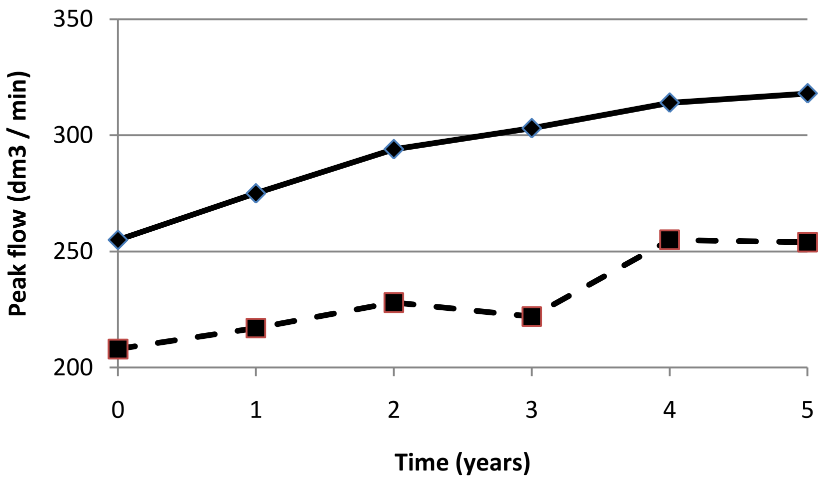
16. The table shows the proportion of different bases in DNA extracted from four different species.

	Adenine	Cytosine	Thymine	Guanine
Human	30.8	19.9		
Chimpanzee	27.2	22.8	27.2	22.8
Shrew	26.7			23.3

(a) Fill in the missing data in the table [2]

(b) Compare the data of the shrew and the chimpanzee [2]

17. Smoking can impair lung function. An investigation was carried out into the effect of smoking on lung function over 5 years. The peak flow rate (a measure of lung function) is the maximum volume of air expelled from the lungs in 60 seconds ($dm^3\ min^{-1}$). Two female volunteers, one a smoker (dashed line) and one a non-smoker (solid line) were both aged 12 at the start of the study. They both had their peak flow measured once a year for five years. The results are shown on the graph below.



(a) Describe the data for the non-smoker. [1]

(b) Compare the data from the two volunteers. [3]

18. In 1978 the population of Elephant seals at Macquarie Island off the coast of Antarctica was estimated at 140 000. It was thought that the population had declined by 75% over the previous 10 years. In 1998 a study estimated the island population to have recovered to 580 000.

(a) Calculate the estimated population of Elephant seals in 1968. Show your working. [2]

(b) Calculate the percentage increase in Elephant seal numbers between 1978 and 1998. Show your working. [2]

(c) Estimate the rate of increase in seals per year over this twenty year period. Show your working [2]

19. A student investigated the species diversity of plants in an area of heath land near his college. The table shows her results.

Plant species	Number of plants per square meter
Mat grass	10
Heath bedstraw	9
Bell heather	4
Sheep's sorrel	2
Ling	3
Heath rush	14
Bilberry	1

She decided to use the index of diversity, *d*. This is calculated using the formula:

$$d = \frac{N\,(N-1)}{\sum n\,(n-1)}$$

where N = total number of organisms of all species
and n = total number of organisms of each species

Use this information to calculate the index of diversity, *d* for the plant species on this heath land. Show your working. [2]

20. Some research scientists investigated the effect of two drugs (alone and in combination) on the growth of a colon tumour in rats. Four groups of ten rats were treated with saline (control group), drug A alone, drug B alone and drug A and B in combination. The volumes of the tumours on day 0 and day 90 were measured by ultrasound. The results are shown in the table.

Treatment	Mean volume of tumour on day 0 mm^3 ($\pm$ s.d.)	Mean volume of tumour on day 90 mm^3 ($\pm$ s.d.)
Control	258 ± 13	587 ± 69
A	243 ± 11	479 ± 54
B	262 ± 9	598 ± 73
A and B	278 ± 15	345 ± 34

(a) What information does the standard deviation provide about the spread of data on day 0 versus day 90? [2]

(b) Calculate the % increase in the volumes of the tumours for the following groups:

Control __________% A __________%

B __________% A and B __________% [4]

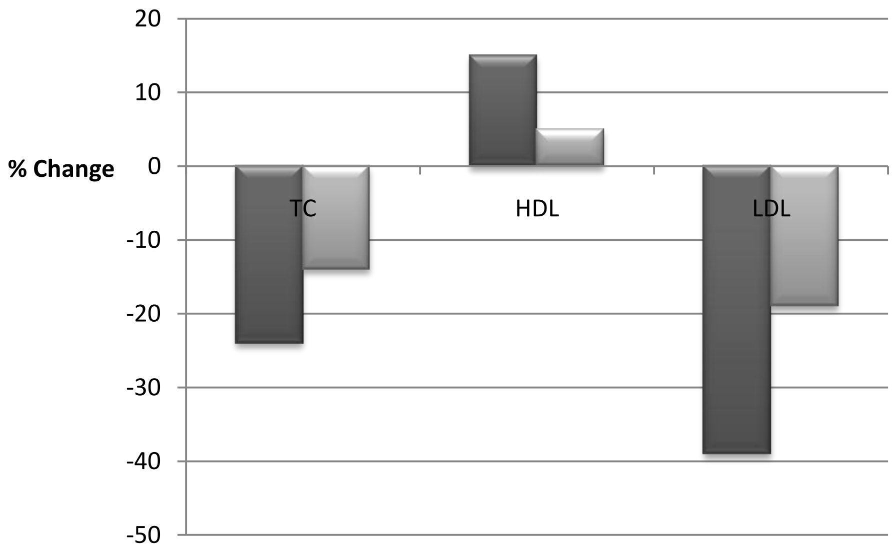
(c) Describe the pattern of results shown by the data. [4]

21. An insect has two antennae. Each antenna is made of 12 000 protein filaments. Each filament is composed of peptide of 400 amino acids.

(a) How many amino acids are present in the two antennae? Show your working [2]

(b) How many bases on DNA are needed to encode for the protein filament? [1]

22. High cholesterol levels and obesity are two major contributors to cardiovascular disease (CVD). Some drugs can lower the total cholesterol and reduce the risk of CVD. Two new drugs, A (darker bars) and B (lighter bars) were given to a group of six obese men. The effects of these drugs on total blood cholesterol (TC), low density lipoprotein (LDL) and high-density lipoprotein (HDL) were studied. The data are the mean % change for the group of men.

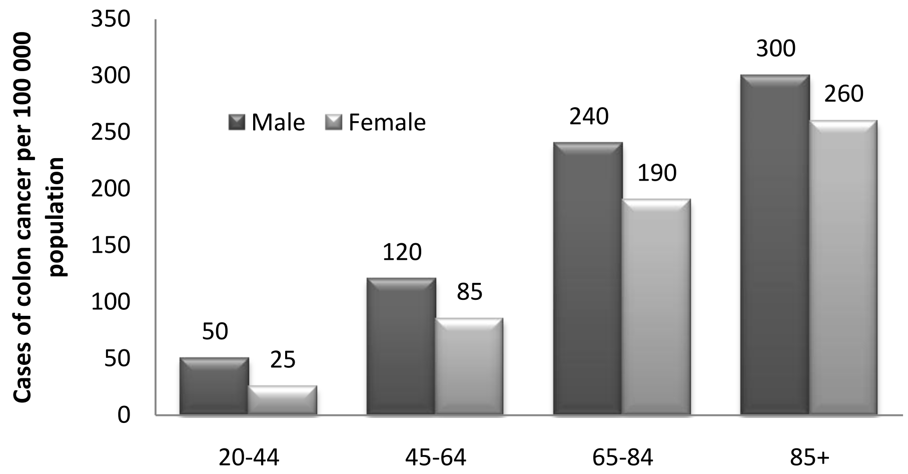


(a) Suggest why the data are expressed as a percentage change. [2]

(b) Compare the effects of the two drugs on TC, LDL and HDL [3].

(c) Give two reasons why the data may not be valid. [2]

23. Colon cancer is a condition that affects both men and women. A recent study of 20 000 people in Africa surveyed the number of cases of colon cancer in men and women of different ages.



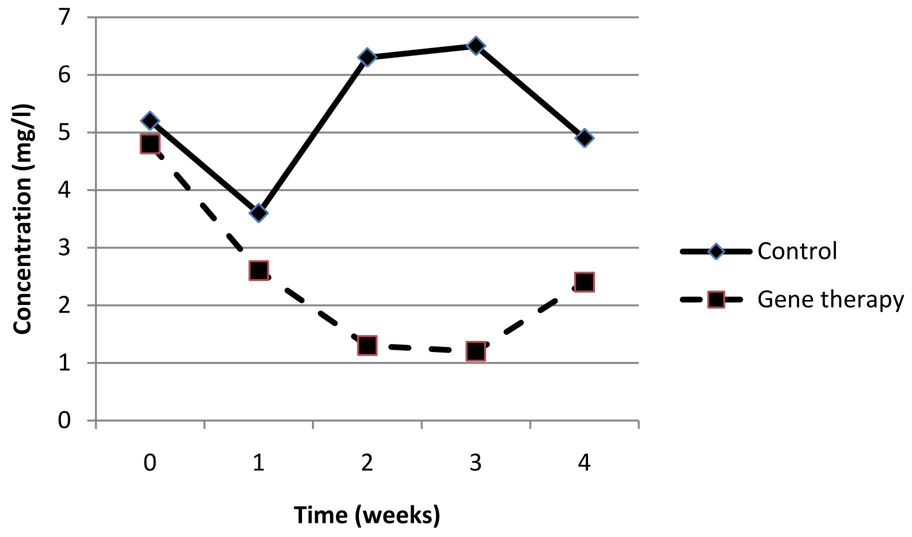
(a) Compare the incidence of colon cancer in the men and women included in the African survey. [3]

(b) Calculate the % increase in male cases between the 45 – 64 and the 85+ age groups. Show your working [2]

(c) A woman is currently aged 32. Calculate her approximate increase in chance of contracting colon cancer by the time she reaches 87. Show your working. [3]

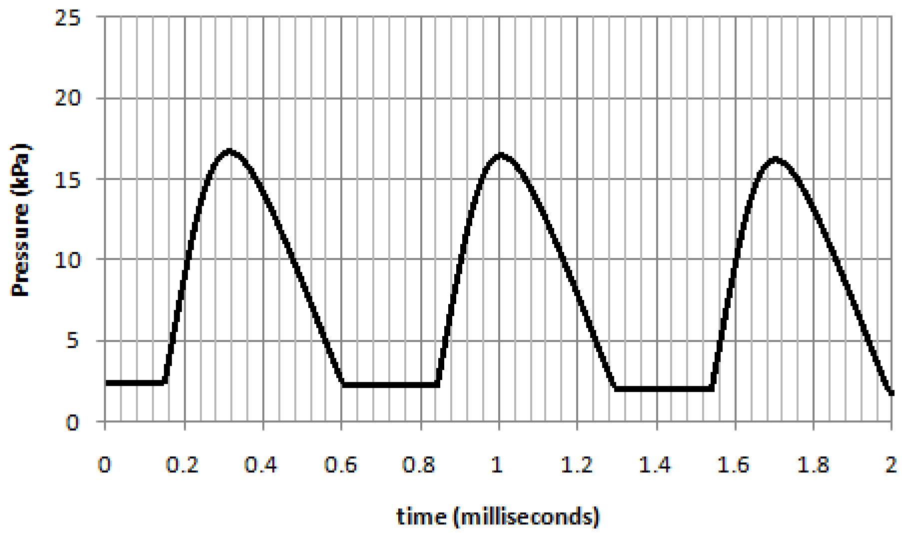
(d) What do the data show about the correlation and causes of colon cancer? [2]

24. The graph shows the effect of somatic gene therapy on the concentration (in milligram per litre) of the amino acid phenylalanine in the blood of female rats over a period of four weeks.



Describe the effect of somatic gene therapy on the levels of phenylalanine in the blood of the rats. [3]

25. The chart below shows the pressure in the left ventricle of a boy aged 7.

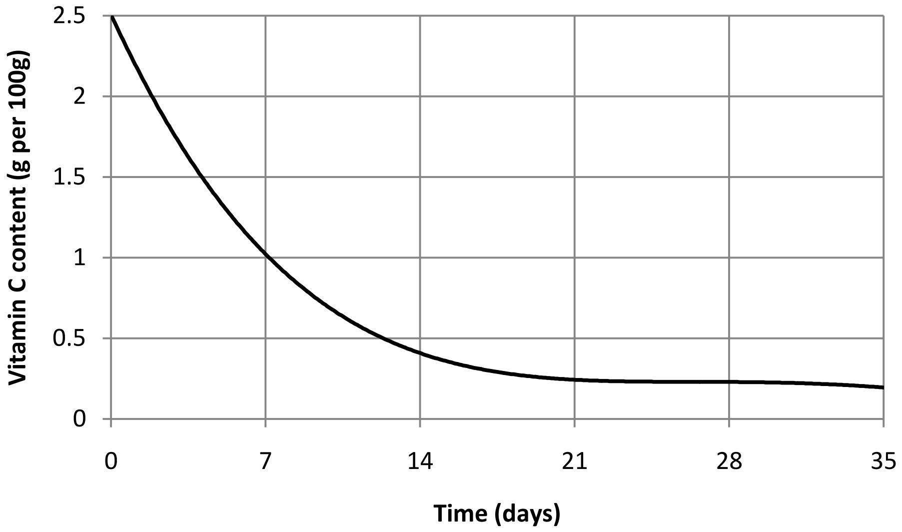


(a) Use the chart to determine the heart rate (in beats per minute) of the boy. [3]

(b) How many times would the boy's heart beat in one hour? [1]

(c) Given the stroke volume of the boy was 150 cm^3 per beat, calculate the cardiac output, in dm^3 per minute. [3]

26. The graph shows how the vitamin C content of a potato changed with time when it was stored over a period of five weeks.



(a) Using the information in the graph, describe the effect of storage time on the vitamin C content of the potato. [3]

(b) Estimate the percentage decrease in vitamin C over the first week. [2]

27. Some students studied a root tip squash under a light microscope. They counted 60 cells that were undergoing cell division and identified their stage of mitosis. Some of their results are shown in the table below:

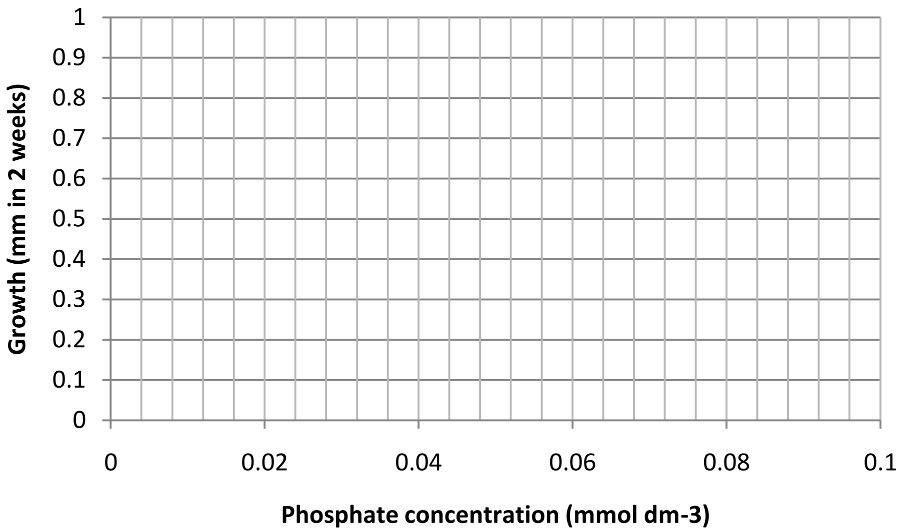
	Prophase	Metaphase	Anaphase	Telophase
Number of cells	15		9	30
% of cells in stage	25		15	
Degrees on pie chart	90	36		

Using the above information deduce the missing values in the table. [5]

28. A student decided to investigate the effect of sodium phosphate concentration on the growth of lettuce seedlings. She grew seedlings in a standard soil under controlled conditions of temperature, light intensity and humidity. Her results are summarised below:

Sodium phosphate (mmol dm^{-3})	0	0.02	0.03	0.05	0.1
Growth (mm in 3 weeks)	0.05	0.2	0.4	0.6	1.0

(a) Plot a graph of her results on the axes and draw a line of best fit through the data. [4]



(b) Describe the relationship between the sodium phosphate concentration and growth [1].

(c) The student concluded that phosphate caused the growth of lettuce seedlings. Give **one** piece of evidence that does **not** support this conclusion. [1]

(d) Suggest one improvement to the design of the study that would increase the reliability of her conclusion. [1]

Multi-choice questions

29. The DNA content of lamb's liver cells in a culture medium was measured over a period of 7 days. It doubled every 16.8 hours. The replication rate (in cycles per week is:
A 5
B 10
C 20

30. A muscle fibre has 500 cells in 2 mm. The average width of one cell is:
A 4 µm
B 4 mm
C $4x10^{-3}$ m

31. A picture of a palisade cell in a text book stated the magnification was x10000. The cell was 10 µm long. The picture in the book was:
A 10 cm
B 10 mm
C 1 cm

32. Some students measured the growth of some seedlings they'd planted. At day 1 the average height of 3 seedlings was 2 mm. 33 days later the average height was 3.5 cm.

(a) The rate of growth was:
A 1 cm day^{-1}
B 1 mm day^{-1}
C 1 mm day

(b) The % increase in height was:
A 165%
B 75%
C 1650%

33. A teacher analysed the marks his students got in a calculations test in a biology class. His 10 pupils scored 5, 18, 14, 14, 10, 12, 14, 19, 11, 9.

(a) The mean was:
A 12.8
B 12.2
C 12.6

(b) The mode was:
A 12
B 14
C 10

(b) The median was:
A 12
B 13
C 14

(d) He concluded all his students would benefit from buying, reading and practicing the examples in *Surviving Maths in AS Biology* published by CT Publications. His conclusion was:

A True
B True
C True

Section 4: Answers to the Exam Questions

Marking you answers is not just about finding whether you got the questions right or wrong! Thoroughness and careful scrutiny of the mark schemes, going back to work out what went wrong are the hallmarks of the A-graders. If you wannabe an A-grader then you'd better act like it. Mark the questions in turn and go back and see what went wrong. Identify which questions you tend to make common errors on, and know what those common errors are. That way, you'll be aware of them and are less likely to make them!

Remember that there are always other acceptable answers; the ones given are a safe interpretation. When the term ORA appears it means "or reverse argument", so A > B (ORA), also means that B < A is an acceptable answer.

Answers to examination-style questions

1. (a) Over the first 8 months there was an overall decrease in concentration with some fluctuations.[1]
After 8 months the concentration remained constant at approximately 5 units [1]

(b) % decrease = ((20 – 5) ÷ 20) x 100 [1] = 75% [1]

(c) Weight loss lowered blood triglyceride for the first 8 months [1]
Then was ineffective [1]

2. (a) Cases reported in village 1 = 66 [1]
Cases reported in village 2 = 77 [1]
Difference in cases = 77 – 66 = 11 [1]

(b) % decrease = ((9 – 3) ÷ 9) x 100 [1] = 66.7% [1]

(c) Both villages have more cases reported between September and March than April through August. [1]
Both villages have a maximum of 9 cases reported in any one month. [1]
Village 2 tended to have more reported cases over summertime than village 1 (ORA). [1]

3. (a) It allows a comparison. [1]
The populations of the different countries were different. [1]

(b) No, the evidence shows a correlation but not causation [1]
Other factors such as exposure to carcinogenic chemicals* may also be involved. [1]
* allow any reasonable alternative factor

(c) Allow 27 – 29. [1]

4 (a) Over the first sixty minutes the blood glucose concentration increases up to a maximum of 10 mmol dm^{-3}. [1] During the second hour the concentration fell slightly to 8 mmol dm^{-3}. [1]

(b)(i) % increase = ((10 – 5) ÷ 5) x 100 [1] = 100% [1]

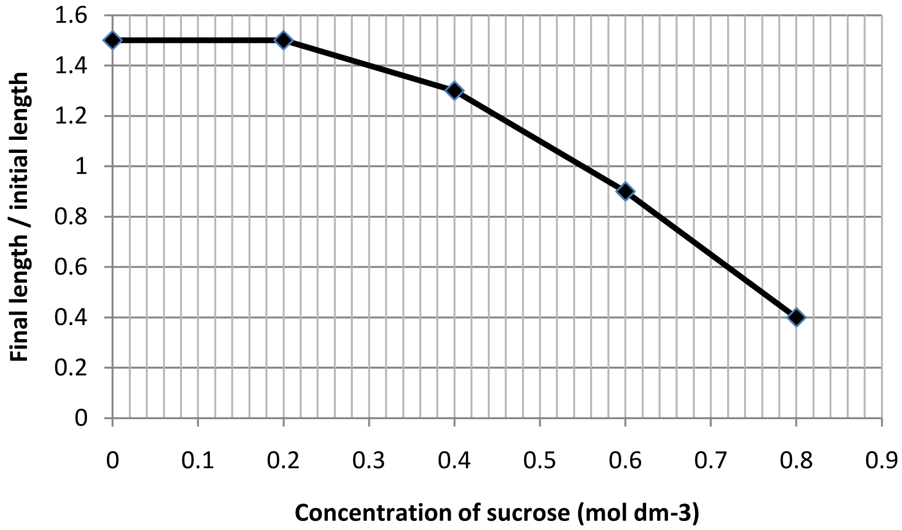
(b)(ii) % decrease = ((10 – 8) ÷ 10) x 100 [1] = 20% [1]

(c) *Any three of …*
Over the first forty-five minutes both men showed an increase in their blood glucose concentrations. [1]
After reaching a maximum concentration, both men's glucose concentrations decreased. [1]

The diabetic man’s level peaked at a higher level (10 versus 9 mmol dm^{-3} [1], 15 minutes earlier than the non-diabetic man’s [1] and did not return to the original level. [1]

5. (a) Plot a graph of the results [1] and connect the points with a smooth curve. [1] Read off the value of concentration when the ratio = 1. [1]

(b)



X-axis labelled correctly [1] Y-axis labelled correctly [1]
Points plotted correctly [1]
Concentration = 0.54 – 0.56 mol dm^{-3} [1]

6. (a) Length of scale bar = 16 mm = 16 000 μm. [1]
Magnification = image ÷ actual = 16 000 ÷ 10 = x1600 [1]

(b) Distance A to B = (48 mm ÷ 16 mm) x 10 μ = 30 μm [1]
30 μm = 0.03 mm
Rate = distance ÷ time, so time = distance ÷ rate = 0.03 ÷ 0.15
Time = 0.2 seconds. [1]

7. (a) People infected with C = 14 ÷ 100 x 895 [1] = 125 people. [1]

(b) 20% of total number = 87.
0.2 x total number = 87 [1]
Total number = 87 ÷ 0.2 = 435 [1]

8. For both, at lower substrate concentrations, as the substrate concentration increased, the rate of reaction increased proportionally. [1]
There is one concentration where the rates of the two reactions are equal. [1]
The initial rate of Q is higher than P (ORA). [1]
At a certain substrate concentration, Q becomes constant. [1]

9. (a) Image width = 18 mm = 18 000µm
Actual width = image ÷ magnification [1]
= 18000 ÷ 12000
= 1.5µm [1]

(b) 1 mm = 1000 µm.
Number = 1000 ÷ 1.5 [1] = 667 [1]

10. (a) Ratio = 22.4 ÷ 22.2 [1] = 1.01 [1]

(b) It allowed the results to be compared, [1] because the masses of the pieces of pear were different. [1]

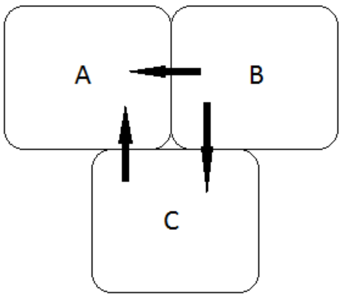
(c) Plot of graph (ratio on y-axis, concentration on x-axis) [1] and read off the concentration when ratio = 1. [1]

11. (a) $\Psi_{cell} = \Psi_s + \Psi_p$

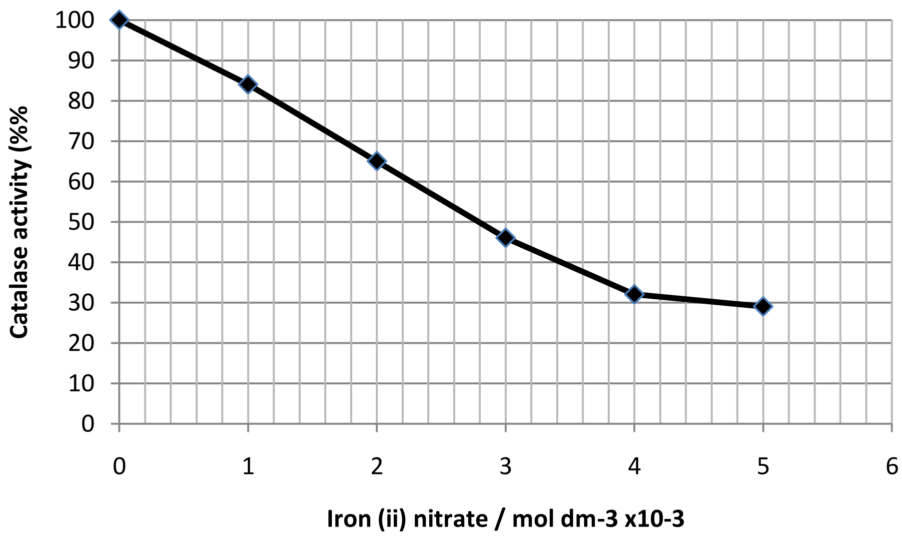
(b)

Cell	Ψ_{cell} *(kPa)*	Ψ_s *(kPa)*	Ψ_p *(kPa)*
A	**– 500**	– 1000	+ 500
B	– 200	– 800	**+ 600**
C	– 400	**– 1100**	+ 700

(c)



12. (a)



x-axis labelled correctly. [1]
y-axis labelled correctly. [1]
Points plotted correctly. [1]
Smooth curve through points. [1]

(b) Draw line across from 50% to curve and down to x-axis. [1]
$2.8x10^{-3}$ mol dm^{-3} [1]

13. (a) Over the first 15 seconds the breathing rate increases with an increasing gradient, [1] after 15 seconds the heart rate remains relatively constant at 83-84 bpm. [1]

(b) % increase = ((84 – 74) ÷ 74) x 100 = 13.5%

14. Inage length = 17 mm = 17 000 µm
Magnification = image ÷ actual = 17 000 ÷ 0.5 = 34 0000

15. (a) (1.24 + 1.32 + 1.28 + 1.29) ÷ 4 [1] = 1.28 seconds (3 sig fig) [1]

(b) Heart rate = 60 ÷ 1.28 = 46.9 beats per minute [1]

16. (a)

	Adenine	Cytosine	Thymine	Guanine
Human	30.8	19.9	**30.8**	**19.9**
Chimpanzee	27.2	22.8	27.2	22.8
Shrew	26.7	**23.3**	**26.7**	23.3

Allow [1] per correct pair.

(b) Both mammals have a ratio of A:T and C:G of 1 [1]
The shrew has 0.5% less A and T and 0.5% more C and G than the chimpanzee [1] ORA

17. (a) Over the five years, the peak flow increased steadily from approximately 260 to 320 with a decreasing gradient. [1]

(b) *Any three of ...*
Both showed an increase in peak flow over the study. [1]
The increase was steadier for the non-smoker. [1]
The maximum peak flow achieved by the smoker was less than the non-smoker. ORA [1].
The smoker had a lower start peak flow than the smoker. [1]
One of the marks is for a relevant use of figures [1]

18. (a) 75% decline means the numbers were 25% of original.
25/100 x original = 140 000, hence:
Original = (140 000 x 100) ÷ 25 [1] = 560 000 [1]

(b) % increase = ((580 000 – 140 000) ÷ 140 000) x 100 = 314%

(c) Number of seals increased by 580 000 – 140 000 = 440 000 seals. [1] over 20 years, so rate = 440 000 ÷ 20 = 22 000 seals per year. [1]

19.

Plant species	Number of plants	n(n-1)
Mat grass	10	10 x 9 = 90
Heath bedstraw	9	9 x 8 = 72
Bell heather	4	4 x 3 = 12
Sheep's sorrel	2	2 x 1 = 2
Ling	3	3 x 2 = 6
Heath rush	14	14 x 13 = 182
Bilberry	1	1 x 0 = 0
	Total = 43	∑ n(n-1) = **364**

$$d = \frac{N\,(N-1)}{\sum n\,(n-1)}$$

$$d = \frac{43 \times 42}{364}$$

= 4.96

20. (a) The standard deviations of the day zero groups were smaller than at day 90 [1] showing the spread of data was larger at day 90 than at day 0. (ORA) [1]

(b) Control = 128% [1] A = 97.1% [1] B = 128% [1] A&B = 24.1% [1]

(c) *Any four of …*

The tumours grew on all treatments. [1]
In the absence of drug the tumours increased by 128%. [1]
Drug A reduced the growth of the tumours by about 30%. [1]
Drug B alone had no effect on the growth of the tumours. [1]
The combination of drugs A and B caused a larger decrease in the growth of the tumours than the drug on their own.[1]

21. (a) Number of amino acids = 2 (antennae) x 12 000 (filaments) x 400 [1]= 9 600 000 [1]

(b) Bases on DNA = 3 x 400 = 1200 [1]

22. (a) A percentage allows a comparison [1] because the initial values of cholesterol were different in each man. [1]

(b) Both drugs caused a decrease in TC and LDL and an increase in HDL [1]

Drug A decreased TC and LDL to a greater extent than B (ORA) [1].
Drug A increased HDL more than drug B (ORA). [1]

(c) Only six men were used. [1]
No standard deviations are shown so no idea about spread. [1]
There's no information about how the men were controlled, e.g. ages boss mass index, diet etc. [1]

23. (a) The number of cases of colon cancer increases with age for both men and women. [1]
In each age group there are more cases for men than women (ORA). [1]
Manipulation of figures, e.g. in the 20 – 44 age group women have a 50% lower incidence of the disease than men. [1]

(b) % increase = ((300 – 120) ÷ 120) x 100 [1] = 150% [1]

(c) At age 32 her risk is 25 / 100 000 = 2.5×10^{-4} [1]
At age 87 her risk is 260 / 100 000 = 2.6×10^{-3} [1]
Increase in risk is $2.6 \times 10^{-3} \div 2.5 \times 10^{-4}$ = x10.4 [1]
Accept increase in risk = $2.6 \times 10^{-3} - 2.5 \times 10^{-4}$ = 2.35x10-3 [1]

(d) The data show that risk of colon cancer is correlated with age. [1]
The do not show that age causes colon cancer. [1]

24 *Any three of …* Over the first two weeks of treatment the concentration of phenylalanine decreased steadily [1]. It remained constant between weeks 2 to 3 [1] and then started to rise again by week 4 [1]. *Figures.* [1]

25. (a) **ERRATUM: The graph x-axis should read seconds.**
Common point = 1.28 – 0.6 = 0.68 seconds [1]
Heart rate = 60 ÷ 0.68 = 88 beats per minute [1]

(b) 88 beats per minute = 60 x 88 [1] per hour = 5280 [1]

(c) Cardiac output = heart rate x stroke volume [1]
Cardiac output = 88 x 150 = 13 200 cm^3 per minute [1]
= 13.2 dm^3 per minute [1]

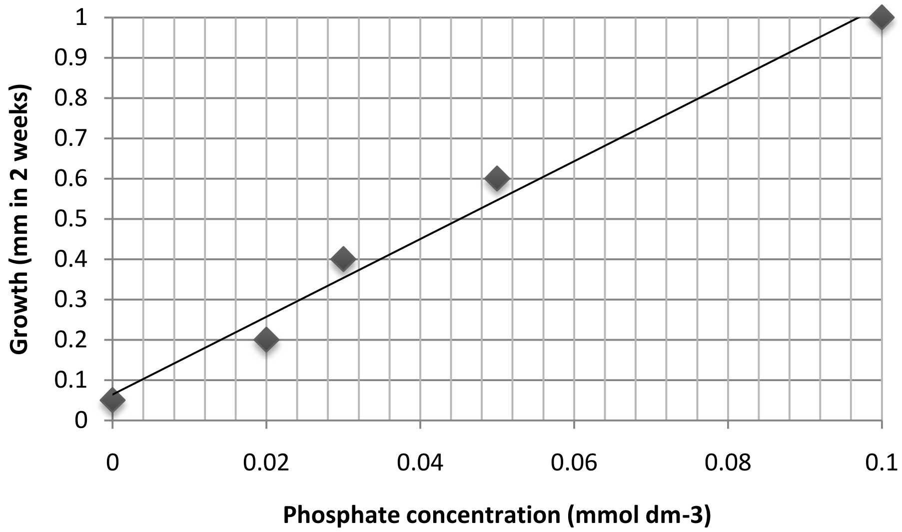
26. (a) Vitamin C content decreased (from 2.5 g/100 g) with time. [1]
The gradient became less steep as time passed. [1]
The vitamin C content remained approximately constant (at 0.25 g / 100g) after 3 weeks. [1]

(b) % decrease = ((2.5 – 1) ÷ 2.5) x 100 [1] = 60.0% [1]

27.

	Prophase	Metaphase	Anaphase	Telophase
Number of cells	15	**6** **60- (15+9+30)**	9	30
% of cells in stage	25	**10** **6 ÷ 60 x 100**	15	**50** **30 ÷ 60 x 100**
Degrees on pie chart	90	36	**54** **15% x 360**	180 **50% x 360**

28. (a)



x-axis labelled correctly [1]
y-axis labelled correctly [1]
points plotted correctly [1]
line of best fit appropriately placed [1]

(b) As the sodium phosphate concentration increased from 0 to 0.1 mmol dm^{-3} the growth of the seedlings increased proportionally [1].

(c) *Any one of ...*
The line of best fit does not go through the origin. [1]
When phosphate is not present, there is still some growth. [1]
There is scatter about the line. [1]

(d) *Any one of ...*
More data points (particularly between 0.06 and 1). [1]
Repeat several times and take the average. [1]
Increase the length of time the seedlings grew. [1]

29. The replication rate (in cycles per week) is: **B 10**
Hours per week = 24 x 7 = 168
Number of cycles = 168 hours ÷ 16.8 = 10

30. The average width of one cell is: **A 4 μm**
2 mm = 2000 μm
2000 μm ÷ 500 = 4 μm

31. The picture in the book was: **A 10 cm**
Image size = actual size x magnification
Image size = 10 x 10 000 = 100 000 μm = 100 mm or 10 cm

32. (a) The growth rate was: **B 1 mm day^{-1}** (mm *per* day)
3.5 cm = 35 mm
Growth was 35 – 2 = 33 mm in 33 days, so 1 mm per day.

(b) % increase was: **C 1650%**
% increase = ((35 - 2) ÷ 2) x *100 = 1650%*

33. (a) Mean = **C 12.6**
Mean = (5 + 18 + 14 + 14 + 10 + 12 + 14 + 19 + 11 + 9) ÷ 10

(b) Mode = **B 14**
14 appears most frequently

(c) Median = **B 13**
Rank 5 9 10 11 ***12 14*** *14 14 18 19*
Central numbers are 12, 14 the average of which is 13

(d) **A TRUE B TRUE C TRUE**
Accurate, precise, valid, you name it, the conclusion was it!

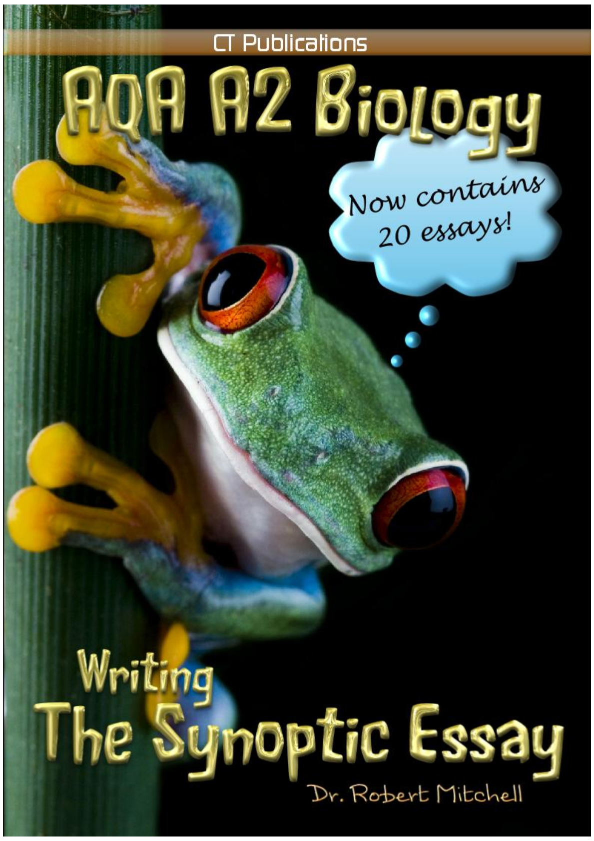
Glossary of HSW terms

Term	Explanation
Accurate	A measurement that is close to the **true value**.
Anomalous data	Measurements that fall outside of the normal or expected range of measured values. Biological variation makes identification of anomalous values difficult, but sampling large numbers allows them to be identified more easily.
Causal link, or causation	A change in one variable that results from (or is caused by) a change in another variable.
Chance	The result of an investigation could have a genuine scientific explanation or be due to chance. Scientist use **statistical tests** to assess the **probability** that a result is due to chance.
Correlation	A correlation shows a relationship between two variables. Evidence of correlation does not automatically imply causation.
Dependent variable	The variable measured for each change in the **independent variable**.
Errors	Errors cause a reading to differ from the **true value**.
Evidence	Data or observations that are used in support of a **hypothesis** or belief.
Fair test	A test in which only the **independent** variable has been allowed to change the **dependent** variable, i.e. one where all other variables are controlled.
Hypothesis	A possible explanation of a problem that can be tested experimentally.
Independent variable	The variable that is changed by the investigator.
Null hypothesis	A **hypothesis** that is worded in terms of there being no difference or association (the negative version of a **hypothesis**).
Precision	Precise measurements are ones which have little spread about the mean value.
Probability	The likelihood of an event occurring. It is different from **chance** because it can be expressed mathematically.
Random distribution	These arise as a result of **chance**. Data will only be **valid** if collected randomly as this avoids **bias** and allows a **statistical testing**.
Reliability	The ability to repeat the results of an investigation. Reliability can be improved by taking more measurement or repeating the experiment many times.
True value	The accurate true value that can be found if measurements are taken with no **errors**.
Validity	Data are valid if they are made by the effect of a single independent variable.
Valid conclusion	A conclusion that can be drawn if supported by reliable data measured by precise instruments to an acceptable degree of accuracy.

Index

Other books by CT Publications

All our lovely books are available from **www.ctpublications.co.uk**



CT Publications

Doing AQA A2 Biology?

The 25 mark essay represents 25% of your final mark for the BIOL 5 Exam.

Don't be one of those students who only focuses on the preparation of the content but then neglects the preparation and planning that the essay demands.

Writing the synoptic essay

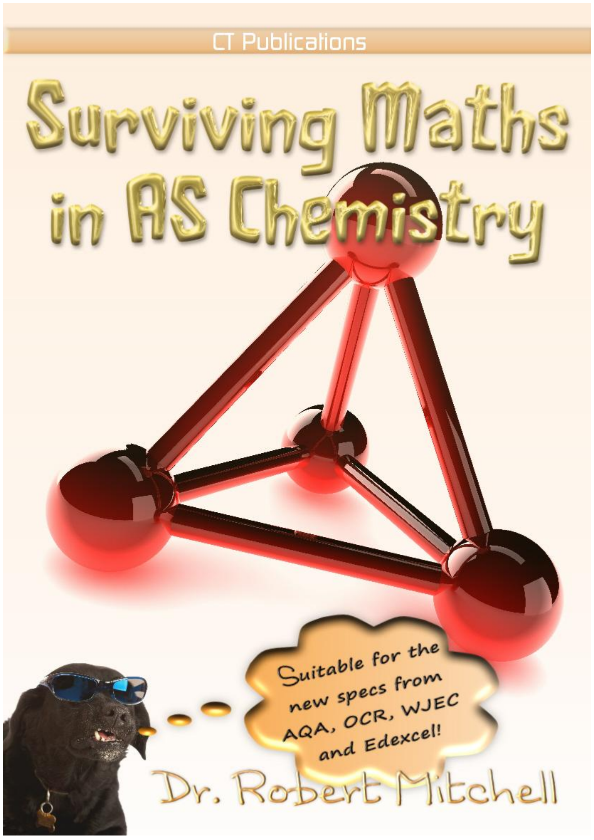
hands you everything you need in order to gain the **maximum marks** in this most challenging part of the AQA Biology A level.

- ☑ An account of what's expected
- ☑ Advice on choosing the right essay
- ☑ How to plan and organise the essay
- ☑ What to do if you get stuck
- ☑ Help on getting your timing right
- ☑ Comes with **20** Sample essays!

CT Publications
40 Higher Bridge Street
Bolton
BL1 2HA
Enquiries@ctpublications.co.uk

RRP £7.99 UK

Biology / Revision Guides / Education
ISBN 978-1-907769-00-9
00799 >
9 781907 769009



CT Publications

Doing AS Chemistry?

Maths and calculations represent up to **30%** of the marks for your AS chemistry exams.

Don't be one of those students who spends hours revising and learning the content but then neglects the practice and preparation the maths questions demand.

Surviving Maths in AS Chemistry

hands you everything you need in order to gain **maximum marks** in this challenging part of the chemistry A level syllabus.

- ☑ Packed with loads of worked examples
- ☑ Tons of exam-style questions from all the boards, all with worked answers
- ☑ Simple, easy to follow methods
- ☑ Covers the minimum entry requirement
- ☑ Suitable for AQA, OCR, Edexcel and WJEC

CT Publications
40 Higher Bridge Street
Bolton
BL1 2HA
enquiries@ctpublications.co.uk

RRP £8.99 UK

Chemistry / Revision Guides / Education
ISBN 978-1-907769-01-6
00899 >
9 781907 769016

Doing AS Biology?

Calculations and data handling represent up to **25%** of the marks for your AS biology exams.

Don't be one of those students who spends hours revising and learning the content but then neglects the practice and preparation the maths questions demand.

Surviving Maths in AS Biology

hands you everything you need in order to gain **maximum marks** in this challenging part of the biology A level syllabus.

- ☑ Packed with loads of worked examples
- ☑ Tons of exam-style questions from all the boards, all with worked answers
- ☑ Simple, easy to follow methods
- ☑ Covers the minimum entry requirement
- ☑ Suitable for AQA, OCR, Edexcel and WJEC

CT Publications
40 Higher Bridge Street
Bolton
BL1 2HA
enquiries@ctpublications.co.uk

RRP £8.99 UK

Biology / Revision Guides / Education

ISBN 978-1-907769-07-8

9 781907 769078 00899 >